Universidade de Aveiro Departamento de Eletrónica, Telecomunicações e Informática,
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Marco Paulo Ferreira Ribeiro

Algoritmos de optimização para redes ópticas de transporte

Optimization algorithms applied to optical transport network

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"We cannot solve our problems with the same thinking we used when we created them."

— Albert Einstein

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Engenharia Eletrónica e Telecomunicações, realizada sob a orientação científica do Professor Doutor Paulo Miguel Nepomuceno Pereira Monteiro, Professor Associado no Departamento de Eletrónica, Telecomunicações e Informática da Universidade de Aveiro e do Professor Doutor Amaro Fernandes de Sousa, Professor Auxiliar no Departamento de Eletrónica, Telecomunicações e Informática da Universidade de Aveiro.

o júri / the jury

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Resumo

Nesta dissertação, é estudado o problema de dimensionamento das redes óticas e é descrito o desenvolvimento de uma ferramenta de planeamento e otimização.

A ferramenta desenvolvida é capaz de otimizar redes reais heterogenias, em termos de capacidade e custo, permite o uso de diferentes equipamentos terminais com diferentes taxas de linha e inclui as funcionalidades de colocação de regeneradores, de multi-hop grooming e de multiplexagem inversa.

Esta ferramenta de otimização foi desenvolvida de forma a tirar partido da geração atual de computadores com processadores múltiplos na abordagem multi-thread, em particular quando é implementado um mecanismo de partilha de informação entre todas as threads.

Por fim, a heurística implementada na ferramenta desenvolvida, bem como as soluções geradas, são também alvo de estudo e de análise nesta dissertação.

A ferramenta desenvolvida poderá servir de base para o estudo do comportamento da rede para diferentes soluções de equipamentos, testar os limites da capacidade da rede, detetar ligações supérfluas ou congestionadas, possibilitar a aglomeração ou desaglomeração de tráfego, determinar a importância de ligações distintas e selecionar locais a intervir, determinar custos de implementação de componentes ou economizar recursos.

Abstract

In this dissertation, the problem of dimensioning optical networks is addressed and the development of a tool for planning and optimization is described.

The developed tool is able to optimize real heterogeneous networks, in terms of capacity and cost, allowing the use of different terminal equipment with different line rates and including different features such as regenerators placement, multi-hop grooming and inverse-multiplexing.

This optimization tool was developed in order to make the most out of the current generation of computers with multiple processors in a multi-threaded approach, particularly when a mechanism of information sharing is implemented among all threads.

Finally, the heuristic implemented in the tool and the solutions generated for a set of case studies are studied and analysed in this dissertation.

The developed tool can be used in the future for the study of the network behaviour for different equipment solutions, for testing the limits of network capacity, detecting redundant or congested links, enabling grooming or inverse multiplexing of traffic, determining the importance of different links, selecting network places for intervention, determining implementation costs of components or saving resources.

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Acronyms

1R	Reamplification without Reshaping or Retiming
2R	Reamplification with Reshaping but no Retiming
3R	Reamplification with Reshaping and Retiming
ADM	Add/Drop Multiplexer
AWG	Arrayed Waveguide Grating
BER	Bit Error Rate
CBR	Constant Bit Rate
DSL	Digital Subscriber Line
DWDM	Dense Wavelength Division Multiplexing
O/E/O	Optical-to-Electrical-to-Optical
FAS	Frame Alignment Signal
FEC	Forward Error Correction
GFP	Generic Framing Procedure
HDLC	High-level Data Link Control
IP	Internet Protocol
ISO	International Organization for Standardization
ITU	International Telecommunication Union
ITU-T	Telecommunication Standardization Sector of the International Telecommunication Union
LASER	Light Amplification by Stimulated Emission of Radiation
MAC	Media Access Control layer
MFAS	Multiframe Alignment Signal
OADM	Optical Add/Drop Multiplexer

OCh	Optical Channel
ODU	Optical Data Unit
OLT	Optical Line Terminal
OMS	Optical Multiplexed Section
OPU	Optical Payload Unit
OSNR	Optical Signal-to-Noise Ratio
OTN	Optical Transport Network
OTS	Optical Transmission Section
OTU	Optical Transport Unit
OXC	Optical Crossconnects
PDH	Plesiochronous Digital Hierarchy
PPP	Point-to-Point Protocol
RPR	Resilient Packet Ring
ROADM	Reconfigurable Optical Add/Drop Multiplexer
SDH	Synchronous Digital Hierarchy
SONET	Synchronous Optical Network
STM-x	Synchronous Transport Module-x (x = 1, 4, 16, 64, 256, . . .)
STS-x	Synchronous Transport Signal-x (x = 1, 3, 12, 48, 192, . . .)
TCP	Transmission Control Protocol
TDM	Time Division Multiplexing
VC	Virtual Circuits
WDM	Wavelength Division Multiplexing
WSS	Wavelength Selective Switch

Chapter 1

Introduction

The need to send more information through a communication medium or channel is one of the motivating factors for continuous research to develop more efficient communication systems. In the past, both conventional copper and wireless methods were good means of transporting data, but they had the limitations of a finite bandwidth and high losses that were proportional to transmitting distances. Glass, as a possible medium of communication, was studied and experimentally deployed as early as the 1960's. Since the beginning of the new millennium, optical networking has matured considerably. Nowadays, we are perceiving big changes related with the telecommunication industry. This industry is always working towards the increase of network capacity. This growth is needed to accommodate the tremendous growth of the Internet and the World Wide Web, in terms of number of users and bandwidth required for the users satisfaction. Meanwhile, the Digital Subscriber Line DSL and modern cable services, that are broadband access technologies, provide bandwidth per user of several megabits per second. Furthermore, these Internet access providers are growing continuously.

Based on Figure 1.1, we can see that between 2009 and 2012 there was a significant increase of the bandwidth provided to the users by the network. "In fact, while high data rate services are emerging and expected to grow with the ratification of standards for 40 and 100 Gigagbit Ethernet, the bulk of client services and associated revenues today and in the medium-term remain at 10Gb/s or lower bit rates (see Figure 1.1). For example, while WDM systems with 40G interfaces have been in deployment since early 2007, by the end of 2008 more than 80 percent of service interfaces deployed in long-haul networks remained at 10Gb/s, with this number forecast to remain essentially unchanged for 2009. Other research indicates that a sizeable portion of 40G WDM deployed in 2009 consisted of 40Gb/s muxponders, with this number forecast to further double by 2012."[1]

If residential customers might want an available bandwidth on the order of $40G$, business customers will want an even better service, whether for transmission of large amounts of data or to the satisfaction of its employees. The international companies, that need to exchange information among their headquarters and to interconnect their international sites, lease lines with more than hundreds of megabits per second and, sometimes, more than thousands of megabits per second. The telecommunication companies that provide these leased services, must be in the edge of the technology always looking to reach the best possible trade-off between cost and bandwidth provision. As the technology evolves, the tendency is to lower the price of bandwidth unit. One of the reasons for this is that new equipment makes better use of bandwidth and improves transmission range. On the other hand, the telecommunication

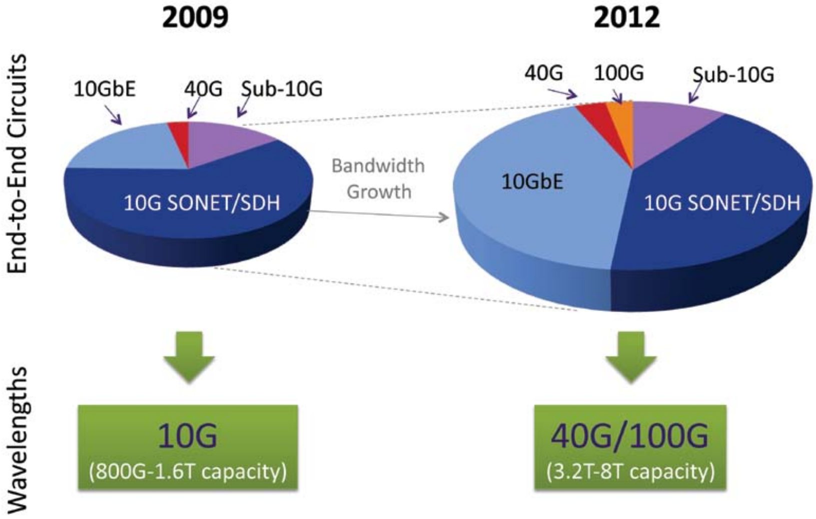

Figure 1.1: Bandwidth Growth at Optical Networks[1].

companies want to capitalize past investments reusing all the infrastructure that they already have in place. These factors have driven the development of high-capacity networks and their rapid transition from the lab research made today, into the commercial deployment of tomorrow.

1.1 Framework and Motivation

The rapid increase of the Internet use is driven by the ever increasing number of services available to the users. Such services go from the simple email to the social networks and have led to the increase of the capacity of the internet servers. Nowadays, network providers need to keep up with these market trends and, in each decision, they absolutely need to take into account the globalization process and the economic factors. Telecommunications companies have been forced to develop their products to make their networks increasingly cost efficient. In order to reduce the costs, they can either reuse network equipment, making it more efficient or install new equipment with a cost benefit ratio that proves to be advantageous.

All optical networks operators avoid by all means to change the network infrastructure due to the associated high cost. In order to avoid these changes, operators try to take full advantage of the available optical fibers, postponing the need to install additional fibers. Today's technology, like Dense Wavelength Division Multiplexing DWDM combined with high spectral efficiency LASER and highly selective filters, may allow demands of 400 Gb/s to co-exist in the network with lower bit-rate channels, on a flexible-grid environment. This happens by creating an efficient "adaptive" channel and subdividing the available fiber spectrum in more granular 25 GHz slots.[2] Such technologies allow a better usage of the available network resources but make the network design process harder to realize since traffic matrices are now more heterogeneous.

As illustrated in Figure 1.2, there are network segments whose names depend on the area covered by them. The Long haul network segment interconnects cities or different regions.

The Metro Access segment interconnects Interoffice network and/or Access network segments and lies within a large city or a region. The Interoffice network segment interconnects groups of central offices within a city or a region and it usually spans from a few kilometres to several tens of kilometres between offices. The Access network segment connects a central office to many individual business or home customers. The Access network segment reach is typically a few kilometres and its main function is to collect traffic from customer locations into the network carrier.

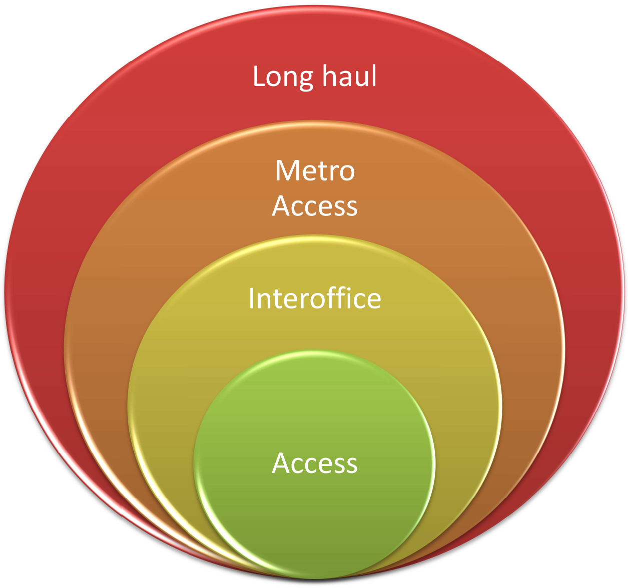

Figure 1.2: Optical fiber architectural overview of a typical national network structure.

In this dissertation, client demands with granularity of 10 Gb/s, 40 Gb/s and 100 Gb/s are considered. The granularities below 10 Gb/s were not considered since usually they reach the Interoffice network segment already multiplexed in these demand granularities. In order to deal with these issues, the work on this dissertation aimed to develop an optimization tool that allows Optical Transport Network operators to design their networks, test several scenarios and select the best solution.

1.2 Objectives

The first aim of this dissertation is to study how the Optical Transport Networks (OTNs) work, in technological terms. This is required in order to identify the several technological alternatives (for example, grooming, inverse multiplexing, regenerators placement, etc...), to support client demands, that can be used in the network design task to reach good design solutions. Then, the aim is to develop an optimization tool that can help OTN operators in their network design task. The aim of the tool is to compute a minimum cost set of OTUs able to support all client demands and to assign an appropriate channel to each OTU compliant with the OTU reach limits, the fibre channel capacities and the WDM continuity constraints. The solution must consider both traffic grooming (single hop and multi-hop) and inverse multiplexing if they lead to lower cost solutions. Moreover, for multiple equal cost solutions, the tool must select the one using a minimum number of WDM channels aiming to maintain the network in an optimized load balance configuration. Finally, the last aim is to define a set of relevant case studies, based on known network topologies, and to run the developed tool on such case studies for testing and validating purposes.

1.3 Structure of the Dissertation

This document is organized in five chapters. The present chapter starts with an introduction and, then, presents the work motivation, objectives, document structure and, finally, the main contributions.

The second chapter, entitled *State of the Art*, explains how OTN works, its advantages, and disadvantages, and how it was defined. Here, the elements that are used for the correct operation in the optical domain are described.

In the third chapter, entitled *Optimization Algorithm*, the addressed network design problem is specified in detail and the OTN network design tool development is described. This chapter includes the description of the heuristic algorithms used in the tool, the tool organization based in blocks and how these blocks interact with each other.

The fourth chapter, entitled *Case Studies and Computational Results*, starts by describing how the case studies were generated. Then, it presents the computational results obtained by the network design tool while solving the case studies. Finally, it analysis the computational results both in terms of toll efficiency and solution characteristics.

Finally, in the *Conclusions* chapter, the main conclusions of the work are discussed and some topics for future research are pointed out, including additional improvements that can be added to the tool and the advantages that can be obtained by such improvements.

1.4 Contributions of the Work

The main contribution of this work is the development of an heuristic algorithm for the OTN network design task. The algorithm is based on a multi-thread multi-start local search strategy to optimize the cost of the network in the presence of heterogeneous client demands and considering a wide range of engineering solutions and constraints whose combination is hard to address, such as single and multi-hop grooming, regenerator placement and inverse-multiplexing. The algorithm solution includes two non standard features and their use are original contributions of this work.

First, the multi-thread approach is the main non standard feature. The shared memory mechanism is a proposal that saves the computation of threads: they run the channel assignment task only if it is worthwhile (*i.e.*, only when their solution is potentially better then the one in the shared memory). The computational results show a drastic improvement in the number of cycles run by unit of time (since it is able to use the full CPU capacity of the computational platform) which has a positive impact on the quality of the best solutions found.

Second, instead of working with a pre-computed set of candidate paths (the common approach of almost all works on this subject), which are usually given by a k-shortest path algorithm, a non-standard shortest path algorithm is used whenever a path is required for a new OTU. This has the main advantage of not taking out from the search any feasible solution. Note that the devised non-standard shortest path algorithms are themselves also very different from other works.

Chapter 2

State of the Art

Deploying OTN switching technology in transport networks is one of the most promising solutions to meet the growing capacity demand and to manage the increasingly complexity and dynamics of the traffic generated by advanced IP-based services. This chapter provides an overview of OTN and the supporting technologies.

2.1 Optical Transport Network OTN

2.1.1 Introduction

The International Organization for Standardization ISO[1] propose a classical breakdown of the different layers in a network as shown in Figure 2.1. The lowest layer in the hierarchy

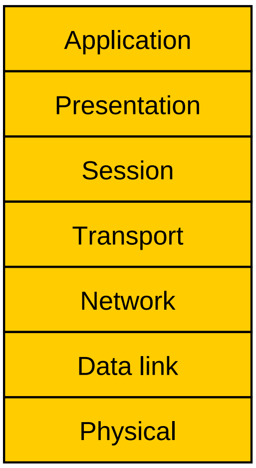

Figure 2.1: The classical breakdown of layers in a network proposed by ISO.

is the physical layer, which provides a 'pipe' with a certain amount of bandwidth to the layer above it and it may be based on different media such as optical, wireless, coaxial or twisted-pairs.

[1]The organization's name would have different acronyms in different languages - e.g. IOS is English, OIN in French - so it adopted the short name ISO, based on the Greek word 'isos' meaning equal.

The layer above is the data link layer, which is responsible for framing, multiplexing and demultiplexing data, sent over the physical layer. Here, the protocol defines how data is transported over a physical link. The layer two protocol divides the data into 'blocks' called frames. These frames are then transmitted to the physical link with proper frame delimitation for correct reception. There are layer two protocols suitable for point-to-point communications (for example, the Point-to-Point Protocol PPP) while others are aimed for point-to-multipoint communications (for example, Ethernet and the High-level Data Link Control HDLC. The last ones must implement, though, a Media Access Control (MAC) layer.

The next layer is the network layer that provides datagram[2] or virtual circuits VC[3] services to the higher layer. The predominant network layer today is Internet Protocol IP that provides end-to-end routing of IP datagrams from their source host to their destination host.

Next, we have the Transport layer that is responsible to ensure the end-to-end, in-sequence, and error-free delivery of data messages. One of the well known protocols operating in this layer is the Transmission Control Protocol TCP.

On the top, we have the Session, Presentation and Application layers that are high level layers implemented on the end node applications.

The predominant protocols in backbone networks today are SONET/SDH, Ethernet, and OTN. These protocols belong to the lower layers (Physical and Data Link) in the ISO hierarchy shown in Figure 2.1. The first generation of optical networks were the Plesiochronous Digital Hierarchy PDH and the SONET/SDH. Both protocols were very successful. The main feature of SONET/SDH, like also PDH, is the support of Constant Bit Rate CBR connections. For efficiency reasons, it multiplexes these connections into higher speed optical connections by using Time Division Multiplexing TDM. Another important feature of SONET/SDH is that it provides a carrier grade service of high availability. Despite of being originally designed for low speed voice traffic, and also for CBR connections, aggregated up to 51 Mb/s, now it also supports data connections. This allows packet traffic with link transmission rates of tens of gigabits per second to be supported. This is made possible with the data link layer protocols that adapt packet traffic to CBR connections. For instance, the Generic Framing Procedure GFP is an adaptation method that works for a variety of data networks, including IP, Ethernet, and Fiber Channel. The OTN technology builds upon the concepts of SONET/SDH, but it was aimed to support all types of data traffic, even to support SONET/SDH traffic. Furthermore, OTN has been refined to operate at very high transmission rates, and it has a complete and flexible set of operation and management features. In a metro network topology, there are several types of client layers such as Gigabit Ethernet, 10-Gigabit Ethernet, Fiber Channel, Resilient Packet Ring RPR as well as SONET/SDH. The Fiber Channel is used in the storage-area networks to connect computers and their peripherals.

OTN uses, in its layers, several possible features of Wavelength Division Multiplexing WDM. In the following, the most noteworthy features are inumerated:

- **Lightpath topology -** This is a virtual graph with the network nodes and with links (between nodes) representing lightpaths. The lightpath topology is the connectivity topology seen by the higher layers and can be adjusted to their characteristics (for example, in a IP network that is above the optical layer, the lightpaths look like links

[2]Datagrams are data packets individually routed end to end, with no associated connection.

[3]A virtual circuit has an associated routing path through which all associated data packets are routed and can be associated to some quality-of-service parameters, such as bandwidth, packet drop rate, etc...

OTN (G.709)	line rates[Gb/s]	SONET SDH	line rates[Gb/s]
OTU1	2.666	STS-48 / STM-16	2.488
OTU2	10.709	STS-192 / STM-64	9.953
OTU3	43.018	STS-768 / STM-256	39.813
OTU4	111.809		

Table 2.1: OTN line rates compared with SONET/SDH line rates.

between IP routers).

- **Wavelength conversion -** In the optical network, it is common that some lightpaths change their assigned wavelength along their route. Wavelength conversion can be used either to improve the utilization of network capacity or as a means to circumvent the maximum transparent reach problem.

- **Survivability -** This is a "security" configuration measure. For instance, if there is a failure in a fiber link, the survivability feature allows the affected lightpaths to be rerouted over alternative paths automatically. This provides a higher degree of resilience in the network.

- **Transparency -** This refers to the fact that the lightpaths may have a different variety of bit rates. This enables the optical layer to support a variety of higher layers simultaneously. It is usual to find in the network lightpaths between pairs of SONET terminals, or between pairs of IP routers, showing that lightpaths can carry data at different bit rates and with different protocols.

- **Wavelength reuse -** Multiple lightpaths can use the same wavelength as long as they do not overlap on any fiber link. This characteristic allows the network to support a large number of lightpaths using a smaller number of wavelength.

- **Circuit switching -** The ligthpaths in the network can remain in operation for very long periods of time but they also can be set up and tear down on demand. With the new incoming technology, the process of circuit switching tends to be more dynamic and this property comes from new services and capabilities developed.

2.1.2 Optical Transport Network Technology

OTN, sometimes also referred as G.709 (that is an ITU-T recommendation), was designed to transport data packet traffic (such as IP and Ethernet) over fiber optics, as well as traffic that already exists in the networks (in particular, SONET/SDH traffic). OTN is also called the digital wrapper technology because it "wraps" any client signal.

The line rates are expressed in a layer of OTN hierarchy named Optical Transport Unit OTU. Line rates of OTU1, OTU2, OTU3 and OTU4 are shown in Table 2.1. In this table, we can also compare the OTU line rates with the SONET/SDH line rates (note that OTU4 does not have one direct match to the frames in SONET/SDH). The frames in SONET are named Synchronous Transport Signal-x STS-x where x can have the values 1, 3, 12, 48, 192,...

On the other hand, the frames in SDH are named Synchronous Transport Module-x STM-x where x can have the values 1, 4, 16, 64, 256,...

The main OTN capabilities are:

1. **Asynchronous Timing -** The OTN frames have an asynchronous mapping of client signals. Here, the clock that generates the frames can be a simple free running oscillator. To account for any mismatch between the clocks of the OTN frames and the client signal, the OTN payload floats within the frame. OTN also has a synchronous mapping where the clock to generate the OTN frames is derived from the client signal. Using simple free-running oscillators can simplify implementation and reduce costs.

2. **Management -** OTN provides structure for monitoring a connection end-to-end and over various segments. At any given point, up to six monitoring segments may overlap. An example application would be a connection of a network "A" that passes through another network "B"; that is, "B" is serving as a carrier for network "A". In this example, the operators of both networks must monitor the connection as it passes through "B", using their own set of monitoring and managing signals, that must be operating in tandem. Then, because an SONET/SDH frame can be transported in one OTN frame, the support monitoring and managing of the signal at the section, line, and path levels, are not affected. The SONET/SDH frame overhead also includes signal identification, Bit Error Rate BER measurement, and communicating alarm information.

3. **Forward Error Correction FEC -** OTN has been designed for high data transmission rates, as shown in Table 2.1. At very high data rates or over very long distances, noise is significant and becomes a problem when ensuring low bit error rates. Forward Error Correction FEC is critical to achieve these low bit error rates. FEC had already been used in SDH but based on proprietary coding schemes that rely on making use of unused section overhead bytes to carry the redundant FEC bytes. Since the number of bytes is limited, the performance is also limited, and interoperability between different vendor equipment cannot be guaranteed. OTN has been designed to carry FEC overhead and employs a strong FEC using the $(255, 239)$ Reed-Solomon code. This code has less 15% of redundancy than the proprietary ones used in SDH and can correct up to 16 bytes in a block of 255 bytes.

4. **Protocol transparency -** OTN provides a constant bit rate service. It includes operations, administration, and management of its connections which is transparent to its clients. Therefore, it can carry all types of data packet traffic including IP and 10-Gigabit Ethernet, as well as SONET/SDH frames. OTN frames can carry entire SONET/SDH frames including overhead without modification. Table 2.1 shows that OTN line rates are 7% higher than SONET/SDH line rates due to its additional overhead and FEC information.

2.1.3 OTN Hierarchy

This section is based on [6]. The optical layer is a complex entity that performs several functions, such as multiplexing wavelengths, switching and routing wavelengths, and monitoring network performance at various levels in the network. Figure 2.2 shows the layers of the OTN hierarchy. In this figure, we can see that the optical layer is divided into three sublayers: the Optical Transmission Section OTS, Optical Multiplexed Section OMS, and

Optical Channel OCh. The highest optical layer is Optical Channel OCh that takes care of end-to-end routing of lightpaths[4]. A lightpath may traverse many links in the network, in which it is multiplexed with many other wavelengths carrying other lightpaths, and it is possible to get regenerated along the way. Each link between Optical Line Terminal OLTs or OADMs represents an optical multiplexed section carrying multiple wavelengths. Each OMS consists of several Optical Transmission Sections. An OTS is the portion of the link between two optical amplifier stages, sometimes also called segments.

The communication to the electronic layer is made through the Optical Channel OCh. In the OTN architecture, the electronic layer above OCh layer is the Optical Channel Transport Unit OTU layer, which deals with individual optical links. The electronic sublayer above the OTU layer is the Optical Channel Data Unit ODU layer, which is for connections composed of multiple optical links. The OTU and ODU layers have similar functions as the section, line, path layers of SONET/SDH.

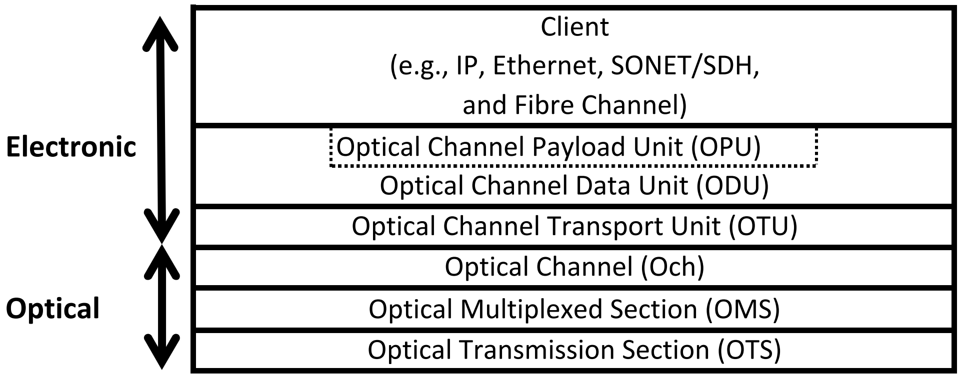

Figure 2.2: OTN hierarchy.

The OTU is similar to the section layer of SONET/SDH, where now the OCh layer provides optical connections between 3R regenerators. The OTU layer adds overhead to delineate OTN frames, provide identification of the optical connection, monitor Bit Error Rate BER performance, carry alarm indicators to signal failures, and provide a communication channel between the end points of the optical connection. The OTU layer also adds the FEC to the OTN frames, scrambles the frames before transmission and provides synchronization information for multiframes. Multiframes are used to send messages over multiple OTN frames and it has a fixed period that must be a power of two. For example, a 256-byte message can be sent through a single overhead byte over 256 frames. The Optical Channel Data Unit ODU supports up to six tandem connection monitoring. Each monitoring provides identification, monitors BER performance, carries alarm indicators and provides communication channels to the end points. The ODU layer includes the Optical Channel Payload Unit OPU sublayer that adapts client signals to the OTN frames.

It is noteworthy that the layers help the operator to break down the management functions necessary in the network. For example, dropping and adding wavelengths is a function performed at the OMS layer. Monitoring optical power on each wavelength also belongs to this layer but monitoring total power belongs to either the OTS layer or the OMS layer, depending on whether or not the optical supervisory channel is included.

[4]The term lightpath refers to an all-optical channel trail between two nodes.

2.1.4 Frame Structure

This section is based on [6]. The structure of the OTN frame is presented in Figure 2.3. Frames are serially transmitted starting in row 1, and per row from the left to right (the frame is scrambled before being transmitted).

The frame structure is organized in 4 rows and 4080 columns of bytes. Each row is composed of 16 interleaved FEC blocks of 255 bytes which gives a total of $16 \times 255 = 4080$ bytes. Each block has 1 byte of overhead, 238 bytes of payload, and 16 bytes of redundant FEC bytes. Since 16 blocks are interleaved and each block can correct up to 8 bytes of errors, bursts of errors can be corrected up to $16 \times 8 = 128$ bytes. From Figure 2.3, we can see that OTU and ODU overheads are in columns 1 through 14. While the first row transports the OTU overhead, rows 2 to 4 transport the ODU overhead. The OPU overhead is transported in columns 15 and 16 of the frame. The overhead of the frame have very different features.

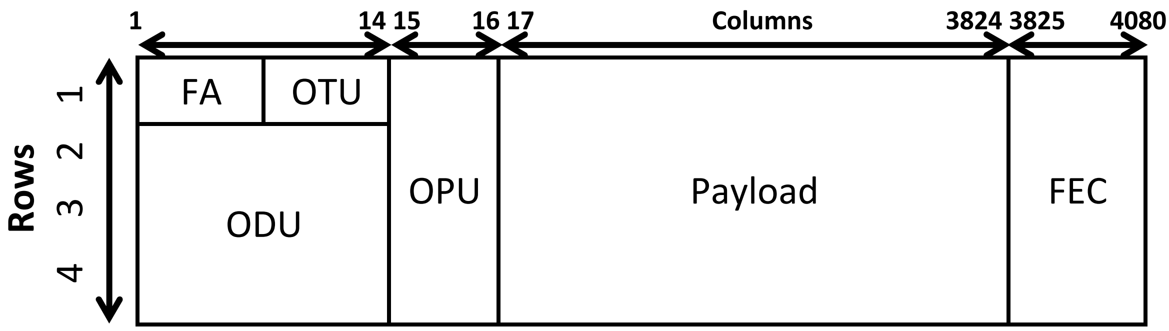

Figure 2.3: OTN (G.709) frame structure showing the location of the overhead bytes.

Some of these overheads parts are:

- **Frame Alignment Signal FAS -** It is located in the first 6 bytes of the first line of the frame. This part is used to delineate the frames (when the frame is scrambled, these 6 bytes are not moved).

- **Multiframe Alignment Signal MFAS -** Some of the overhead fields carry information that is dispersed over multiple frames, referred to as multiframes. The MFAS byte is incremented every frame providing 256 values indicating the number of the frame within a multiframe. The MFAS byte is used to synchronize bytes of multiframes.

- **OTU's overheads -** This overhead is subdivided in three smaller parts: Section Monitoring, General Communications Channel and reserved bytes for future standardization. The Monitoring section has bytes of trail trace identifier that identifies two end points of the optical connection, and alarm signals that are error indicators and backward incoming alignment error. The General Communications Channel provides a clear channel connection between termination points and it has 2 bytes.

- **ODU's overheads -** Here, we can find lots of overheads information. For example there are 3 bytes for Path Monitoring that are used to monitor the end-to-end path. Then, we have 18 bytes of Tandem Connection Monitoring that may be used by a network operator to monitor the error performance of a signal. In addition, we can find a reserved space for Fault Type and Fault Location, General Communication Channel and Automatic Protection Switching/Protection Communication Channel. This last space provides a channel for carrying signalling information for automatic protection switching, and uses 4 bytes. The remaining bytes are reserved for future standardization or for experimental purposes.

- **OPU's overheads -** This overhead is mainly used to adapt the client signals to the OTN frame, dealing for instance with slightly different rates among client signals. This overhead is divided in two groups: Payload Structure Identifier and Justification. The first group identifies the type of payload being carried in the frame, for example, multiplexed ODU signals, GFP, or test signals. The second group takes care of the lack of synchronism of the client signal and adds or removes a data byte from OTN frame to adjust the mismatch. To protect against errors, the justification value is copied in 3 bytes. A majority vote (i.e., two out of three) is taken to determine if the actual justification value is positive or negative[3].

2.1.5 Multiplexing

OTN supports multiplexing of ODU signals. For instance, four ODU1 can be multiplexed

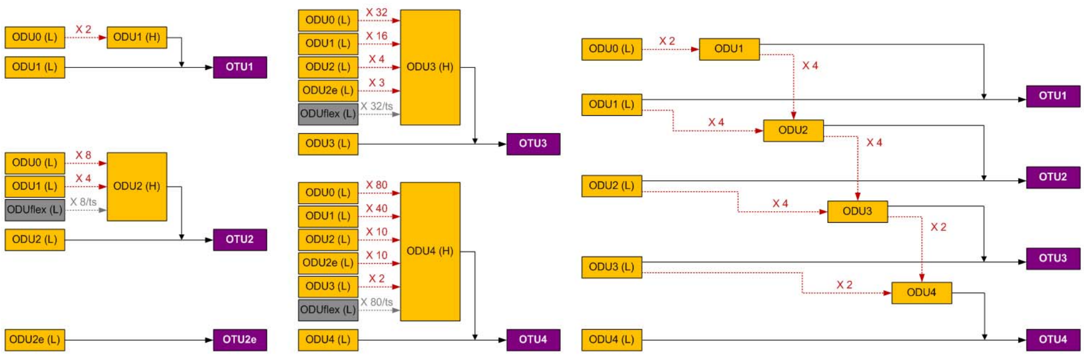

Figure 2.4: Mapping/multiplexing of ODUs into OTUs[4].

into one ODU2, sixteen ODU1 (or four ODU2) can be multiplexed into one ODU3, etc... Consider, for example, the case of one ODU2 carrying four ODU1. In this case, the OTU2 frames are organized into four multiframes, where each multiframe carries the frames of ODU1s. The payloads of the four ODU1 are byte interleaved between them. The OPU overhead of an OTU2 frame carries information in its Payload Identifier byte about the multiplexed signals. The payload type indicates multiplexed ODU signals. The Payload Identifier carries the information whether the signals are ODU1, ODU2, ODU3 or ODU4, and their position in the payload.

Moreover, OTN supports also virtual concatenation, sometimes referred as inverse multiplexing.

Figure 2.4 illustrates the mapping/multiplexing of ODUs into OTUs. The left side of this figure depicts a simplified scheme of single-stage multiplexing of ODUs, showing the maximum number of ODUs of a single rate that can be multiplexed into each OTU (mapping of ODU2e into OTU2e is defined in [5]). The case of multi-stage multiplexing with all intermediate hierarchies, which is useful, for example, for interworking with legacy equipment, is illustrated in the right side of Figure 2.4. Multi-stage multiplexing can introduce extra complexity to optical channel utilization, when compared to single-stage multiplexing. First, unused bandwidth from two or more intermediate ODUs cannot be jointly allocated to form a single new ODU (e.g., two ODU2 carrying only two ODU1 each have a total of eight available $1.25G$ tributary slots, but they cannot be utilized to form another ODU2). Second, an OTU4 obtained from multiplexing two ODU3 entails an upfront bandwidth waste of up to $18 \times 1.25G$ tributary slots.[4].

2.2 Optical Network Elements

In this section, the functionalities of some optical network elements are described. For this purpose, some considerations about the ways of connecting two networks nodes between clients are first given. This can be done using circuit-switched end-to-end optical channels, or lightpaths. A lightpath consists of an wavelength, or optical channel, between two network nodes that are routed through multiple connected nodes. Each link can support a maximum number of wavelengths and this number depends from component to component. The nodes can be configured either to keep the same wavelengths for each lightpath or to convert wavelengths for some lightpaths.

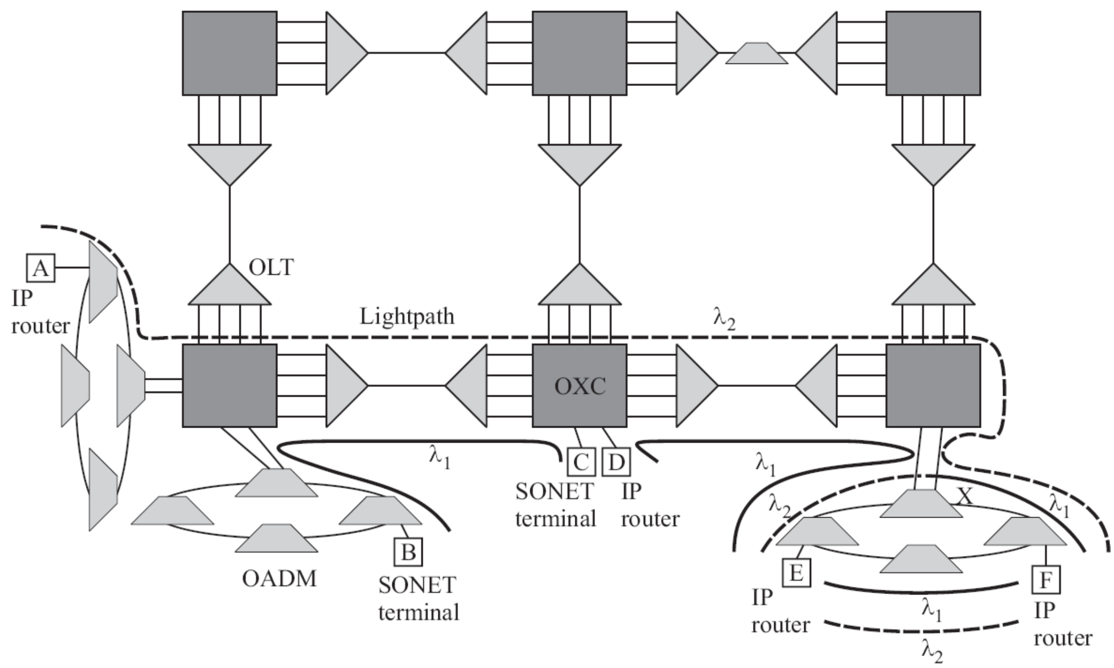

Figure 2.5: A wavelength-routing mesh network showing OLTs, OADMs, and OXCs. The network provides lightpaths to its users, such as SONET boxes and IP routers. A lightpath is carried on a wavelength between its source and destination but may get converted from one wavelength to another along the way.[6]

Figure 2.5 gives an example containing the different network elements that can exist in the network. The figure contains Optical Line Terminals (OLTs), Optical Add/Drop Multiplexers (OADMs) and Optical Crossconnects (OXCs). This figure illustrates the existence of three lightpaths and three optical channels, and their assigned wavelengths (λ). One of the lightpaths (the one from node E to node F) changes its wavelength along its path: it is assigned with λ_2 on link EX and it is assigned with λ_1 on link XF (the wavelength conversion is done at node X). The optical line amplifiers are skipped in Figure 2.5 since they are considered as being part of the fiber network (they are included in the fiber link at periodic locations to amplify the light signal). The OLTs have the responsibility of multiplexing multiple wavelengths into a single optical fiber (in the transmission) and the reverse operation (in the reception). Therefore, the OLT is always at both ends of each point-to-point link. The OADMs are at locations where some fraction of the wavelengths need to be terminated locally and others need to be inserted to other destinations. When the number of ports and wavelengths is high, OXCs are used instead of OADMs.

2.2.1 Optical Line Terminal OLT

As illustrated in Figure 2.5, the OLTs are widely used in the network. Figure 2.6 a) shows two functional elements inside an OLT: transponders and wavelength multiplexers (they also include optical amplifiers that are not shown in the figure). The interface between the client and the transponder may change depending on the client, bit rate, and distance and/or loss between the client and the transponder. The transponder is responsible to adapt the signal coming from the client side of the network into a signal able to be used inside the network (and vice-versa). The transponder typically generates wavelengths in accordance to standards

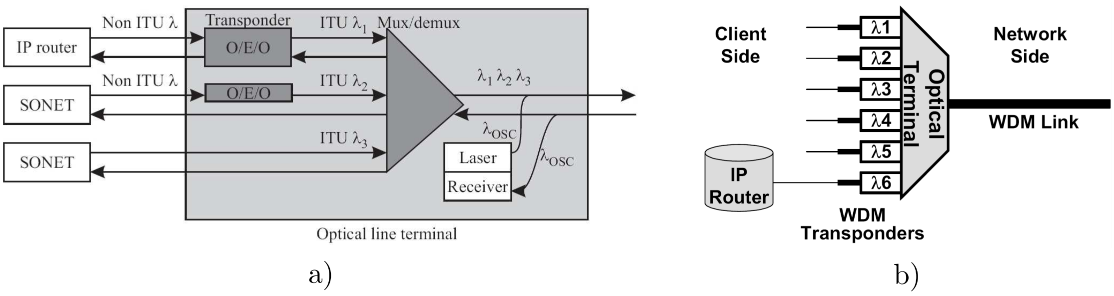

Figure 2.6: a) block diagram of a typical OLT [6]; b) outside view of an OLT[7]

set by the ITU in the $1.55\mu m$ wavelength window, as indicated in the Figure 2.6 a), while the incoming signal may be a $1.3\mu m$ signal. The transponder has the capacity of adding features to the signal. For instance, it can add FEC to signals at $10Gb/s$ or higher or additional overhead for management and monitoring purposes. For these reasons, the adaptation is typically done through an optical-to-electrical-to-optical (O/E/O) conversion. Finally, the OLT also terminates an optical supervisory channel this is carried on a separate wavelength, different from the wavelengths carrying the client traffic.

2.2.2 Optical Add/Drop Multiplexer OADM

OADMs are commercially available since the mid 1990's, although significant deployment did not start until 2000. The name of the element derives from a SONET/SDH ADM,which is capable of adding/dropping lower-rate SONET/SDH signals to/from a higher-rate signal without terminating the entire higher-rate signal. So, the OADM adds/drops wavelengths to/from a fiber without having to go to electronic domain and the only traffic that comes out of the optical domain is the traffic that is dropped or added in the node. The introduction of OADMs in the network led to a reduction of the number of transponders reducing in this way the overall network cost, in particular at high traffic scenarios.

Figure 2.7 a) presents a fixed frequency OADM architecture where a dedicated add/drop structure per fiber is used. In this architecture, if a wavelength or a routing path needs to be changed, a technician has to visit the site and setup the connections manually. The add/drop channels are multiplexed/demultiplexed per direction by Arrayed Waveguide Grating AWG allowing to add/drop all channels to/from all directions. The node architecture presented in Figure 2.7 b) has colorless and directionless functionalities [8]. In this type of architecture, the add/drop structure is shared between all node directions and an optical signal can be sent into any wavelength (colorless) and to any direction (directionless). The add/drop wavelength is sent to a Wavelength Selective Switch WSS where all signals are multiplexed and after which the resulting WDM signal goes through a combiner/splitter module. The combiner/splitter module aggregates all WDM signals that arrive from the different WSSs in the add/drop structure. Finally, the combined signal is transmitted to another WSS module that is connected to all directions and routes the wavelength channels in their target direction. The maximum number of add/drop channels is then limited by the degree of the node and by the number of ports in the combiner/splitter module. Note that this architecture still exhibits internal blocking (please see [8]). Note that, as the add/drop structure is shared, two different signals using the same wavelength cannot be transmitted along the same WSS. The example presented in Figure 2.7 b) illustrates the impact of the node architecture and of the survivability scheme. The results in [9] show that architectures that enable the use of dynamic survivability schemes can save approximately 25% of the network energy consumption, footprint, and CapEx.

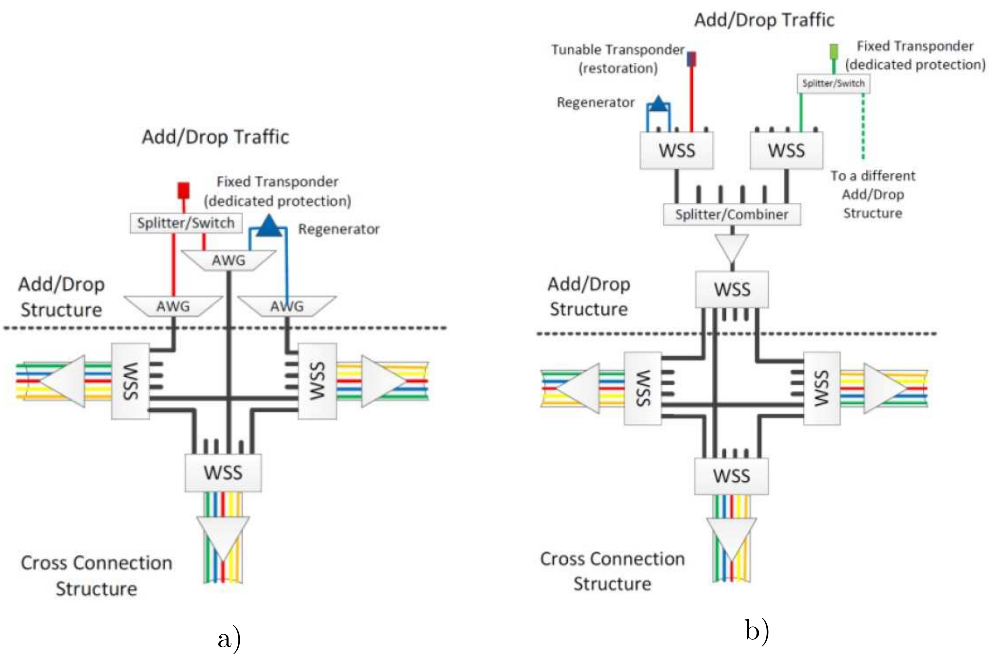

Figure 2.7: ROADMs implementations: a) fixed frequency architecture; b) colorless and directionless architecture. [9]

Optical networks that support optical bypass through OADM (also called "all-optical") has some advantages and disadvantages compared with O/E/O ADM. The advantages are:

1. As the network traffic increases, the all-optical technology is potentially more scalable in cost, space, power and heat dissipation due to the electronics elimination.

2. The optic domain is more independent to the system bit-rate as compared to the electronic domain. For example, OADMs work whether the wavelengths are carrying $10Gb/s$, $40Gb/s$ or $100Gb/s$ signals [5].

3. The elimination of much of the electronics also improves the overall reliability [10]. The removal of much of the electronic equipment in the signal path typically leads to an overall lower failure rate for the connection.

The disadvantages are:

1. The optical signal that goes through the node is not regenerated. Therefore, the optical reach is reduced due to the OSNR degradation.

2. Removing the transponders from some or all of the intermediate nodes of a path also eliminates a error-checking functionality that they provide.

2.2.3 Reamplification, Reshaping and Retiming

There are three types of electronic regeneration techniques for digital data. The simplest electronic regeneration is known by 1R, illustrated on the top of Figure 2.8, where the signal is simply amplified without retiming or reshaping. Although quite inexpensive, the performance of this regenerator technique is worse when compared with the other two types of regeneration. For this reason, the current networks use 2R or 3R electronic regeneration. However, note that optical amplifiers are widely used to amplify the signal in the optical domain without converting it to the electrical domain.

A more complex regeneration technique is the signal regeneration without retiming, also called 2R, illustrated on the middle of Figure 2.8. In this case, the signal is reshaped by through a decision circuit. This technique does not support analog data or different modulation formats [11]. Moreover, this approach limits the number of regeneration steps allowed, particularly at higher bit rates.

The last one is called regeneration with retiming and reshaping, also known as 3R (illustrated on the bottom of Figure 2.8). In this case, the signal clock is extracted from the data signal and the signal is retimed. This alternative completely resets the effects of nonlinearities, fiber dispersion, and amplifier noise. However, retiming is a bit-rate-specific function, and transparency is lost. If transparency is not very important, this is a very attractive approach. This technique essentially produces a"fresh" copy of the signal at each regeneration step, allowing the signal to go through a very large number of regenerators. Another limitation of this technique is the jitter which accumulates at each regeneration step. Note that in all types of regenerators, the input signal is first converted to electronic form, then regenerated and finally retransmitted using a laser (that might use a different wavelength). Note also that these types of regenerators often include electronics dealing with monitoring functions such as FEC performance, for example.

[5] This applies only if the wavelength spacing and the signal spectrum are compatible with the OADM.

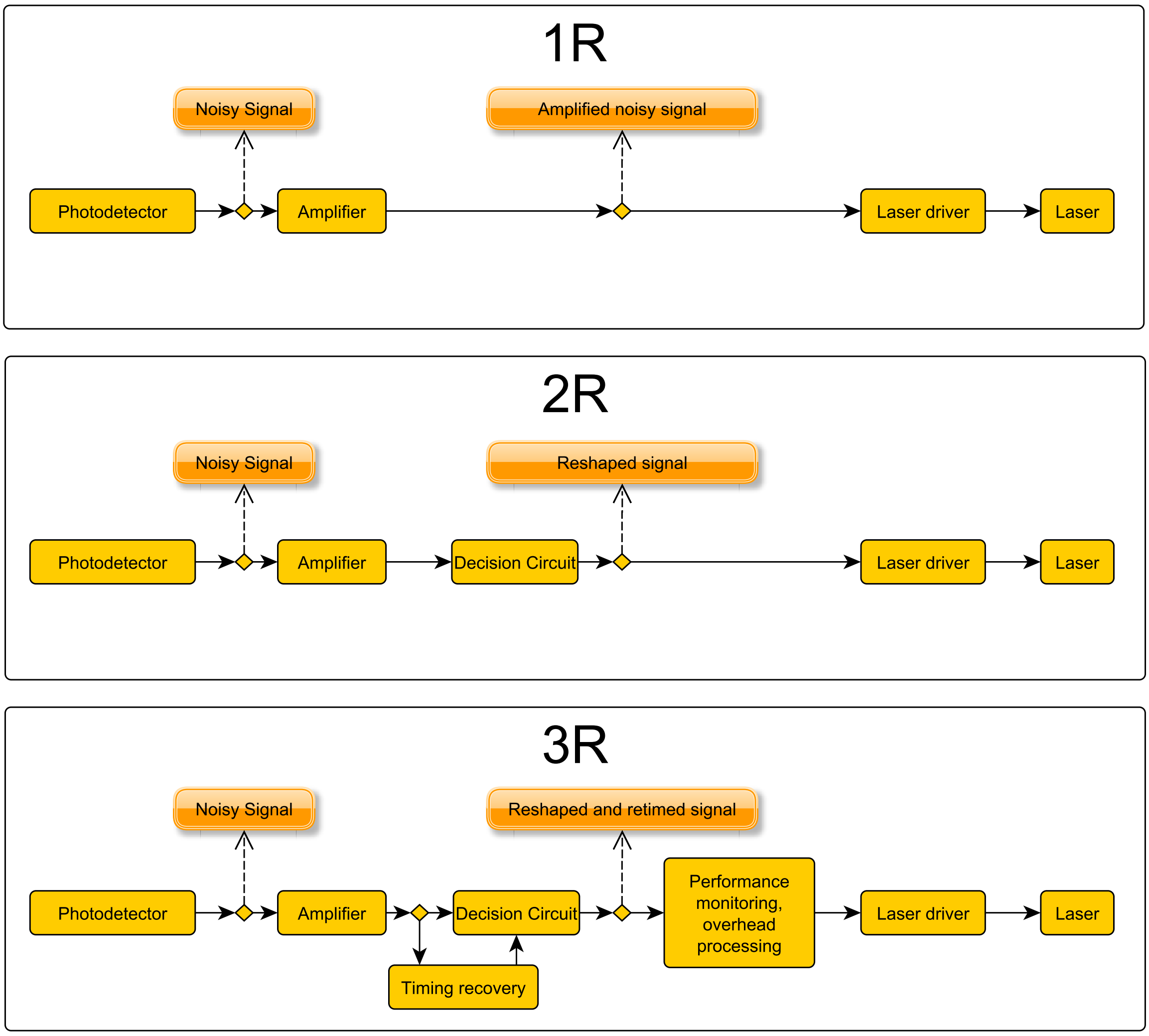

Figure 2.8: Different types of optoelectronic regeneration. 1R Regeneration without reshaping or retiming. 2R regeneration with reshaping. 3R regeneration with reshaping and retiming.

2.2.4 Muxponders

The need for multiplexing is driven by economical factors since it is more cost effective to transmit data in a single fiber at higher data rates instead of using multiple fibers with lower data rates. One way of increasing the transmission capacity on a fiber is to increase the bit rate, but this requires higher-speed electronics. The muxponder typically interleaves the lower-speed streams to obtain an higher-speed stream (*i.e.*, it picks 1 data block from the first stream, the next data block from the second stream, etc...). For example, 64 streams of $155Mb/s$ may be multiplexed into a single $10Gb/s$ stream. Today, the highest transmission rate available in commercially systems is 100 Gb/s.

On the other hand, we might have client streams that cannot be supported individually by the network. In this case, another way to increase the capacity of a network is by WDM. The idea is to transmit multiple wavelengths simultaneously over the fiber.

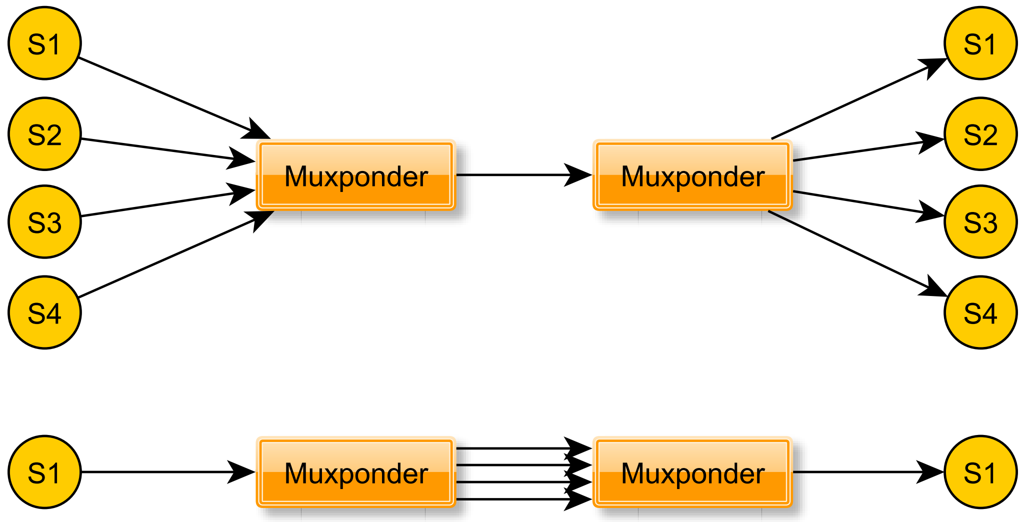

Figure 2.9: Different utilizations of a muxponder into different needs of multiplexing.

Figure 2.9 illustrates the importance of the muxponders on multiplexing process. On top of the figure we can see the normal use of muxponders, that is multiplexing four signals from the client, transmitting the new signal to the destination node where is demultiplexed and delivered to the target client. This multiplexing process has the advantage of reducing the cost and the need of capacity through the link that uses it. The bottom part of Figure 2.9 illustrates another usage of muxponders in a configuration that implements an inverse multiplexing solution. In this case, the muxponder receives one signal from the client/user and "divides" it in four signals with lower bit rate. At the other end, it recovers the original signal to deliver to the final target client. This option is more expensive and it uses more bandwidth but, in some cases it is very useful. For example, consider that the signal $S1$ is $100Gb/s$ and the transponders of $100Gb/s$ and $40Gb/s$ have a reach of $1500km$ and $2000km$ respectively. If the routing path includes a fiber link whose length is $1750km$, the inverse multiplexing approach becomes a viable option since it makes possible the transmission of the $S1$ signal.

Chapter 3

Optimization Algorithm

This chapter describes the implementation of the optimization algorithm. It shows how the program is structured and how each program component was developed. The work was developed according to a meta-heuristic named Multi-Start Local Search. So, this chapter starts by explaining how this basic meta-heuristic works in order to understand how the optimization algorithm was designed. Then, it explains the changes and the evolution of the various algorithm parts till its final version, as well as the changes made to improve the algorithm performance.

3.1 Multi-Start Local Search Meta-heuristic

The program uses a *Multi-Start Local Search Meta-heuristic* [1] as a means to generate multiple solutions. A Multi-Start Local Search algorithm runs multiple cycles where at each cycle two steps are conducted: a first step where an initial solution is computed and a second step where the initial solution is improved through a Local Search procedure, finding in this way a local minimum solution. At the end, the best among all local minimum solutions is the best solution provided by the algorithm. To process an initial solution, a Greedy algorithm is used with some randomness in order to have different initial solutions on each cycle. The initial solutions obtained by the Greedy step are then passed to the Local Search step. Here, the program implements another cycle where at each cycle, the program: (i) computes the best neighbour solution and (ii) moves to the best neighbour solution. The Local Search cycle stops when the best neighbour solution is not better then the current one.

In order to illustrate how Local Search works, consider the small example shown in Figure 3.1. Solution 1 is the first current solution and is the solution generated by the Greedy algorithm. Based on solution 1, the Local Search computes the neighbour solutions 2 to 6. Among such neighbour solutions, the best one is solution 3 and this solution is better than solution 1. Therefore, Local Search repeats its cycle by assuming that the current solution is solution 3. In the second cycle, among all new neighbour solutions, solution 13 is the best

[1] A meta-heuristic in computer science and mathematical optimization, is a higher-level procedure or heuristic designed to find, generate, or select a lower-level procedure or heuristic (partial search algorithm) that may provide a sufficiently good solution to an optimization problem, especially with incomplete or imperfect information or limited computation capacity[12].

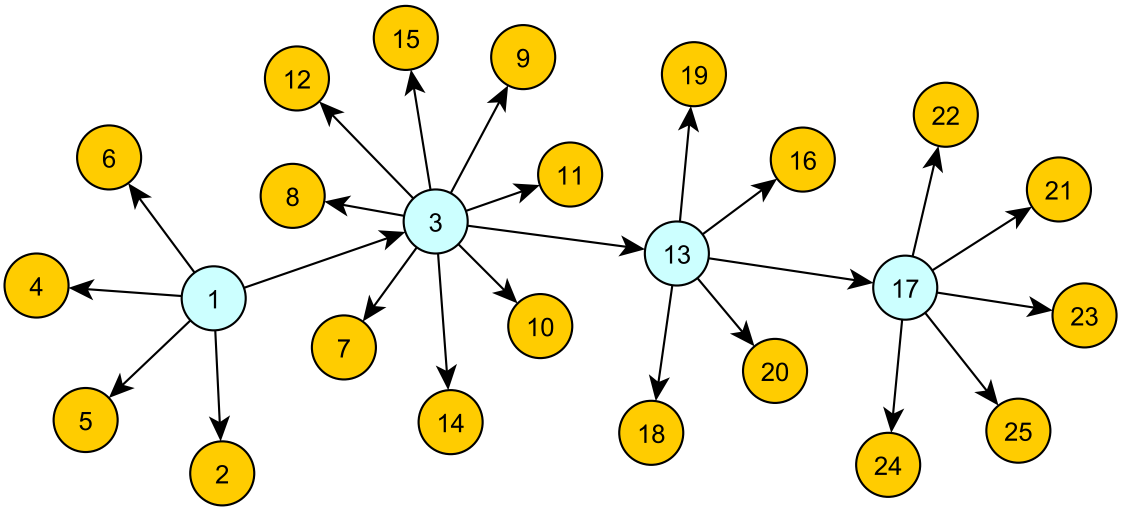

Figure 3.1: Visualization of Local Search working process.

and it is better than solution 3. Now, the Local Search runs a new cycle considering solution 13 as the current solution. In the next cycle, solution 17 is the current solution. In this last cycle, none of the neighbour solutions is better than solution 17. Therefore, based on the initial solution 1, Local Search has found the local minimum solution 17.

In order to illustrate how the overall meta-heuristic works, consider the example shown in Figure 3.2 illustrating a theoretical solution space where all feasible solutions are represented with their cost values. Consider that the solutions marked by the letters $\boxed{\text{A}}$ $\boxed{\text{A'}}$ $\boxed{\text{B}}$ and $\boxed{\text{C}}$ are initial solutions given by the Greedy algorithm. Each of these solutions is then improved by the Local Search algorithm.

The Greedy solution $\boxed{\text{A}}$ is improved by moving to the left (in the Figure) until a Local Minimum solution is obtained with cost around 9 units (the same result is obtained with the initial solution $\boxed{\text{A'}}$). On the other hand, in the $\boxed{\text{B}}$ solution case, the Local Minimum solution is obtained moving to the right with a cost around 11 units. Note that only for the $\boxed{\text{C}}$ solution, the Local Search is able to find the global minimum solution moving to the left with a cost around 5 units. The overall algorithm is stochastic and, therefore, there is a non-null probability that the global minimum is not found. This probability is lower if more Multi-Start Local Search cycles are run and, therefore, code efficiency is very important in the quality of the solutions that the algorithm can find (if the algorithm can run more cycles in the same runtime, it will find better solutions with higher probability).

Remember that both $\boxed{\text{A}}$ and $\boxed{\text{A'}}$ solutions lead to the same Local Minimum solution. Between them, $\boxed{\text{A'}}$ solution is better since, in general, it requires less Local Search cycles to reach the Local Minimum solution (improving, in this way, the overall algorithm efficiency). In general, better initial solutions are obtained by Greedy algorithms and this was the motivation for its use in this work.

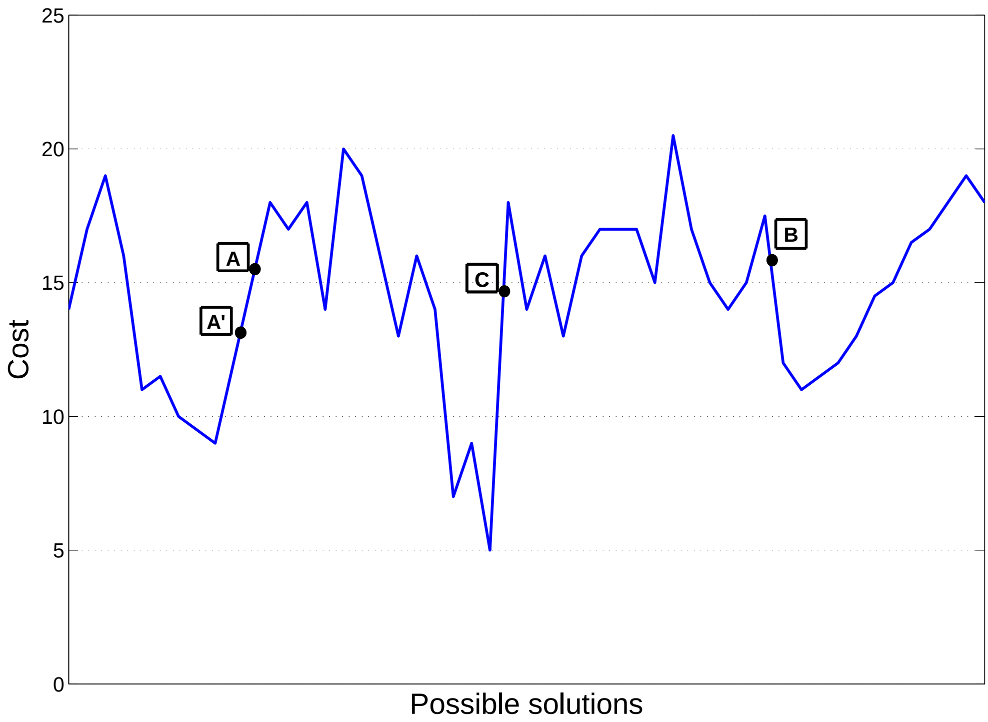

Figure 3.2: Illustration of a theoretical solution space.

3.2 Problem Definition

The aim of the tool is to compute a minimum cost set of OTUs able to support all client demands and to assign an appropriate channel to each OTU compliant with the OTU reach limits, the fibre channel capacities and the WDM continuity constraints. The solution must consider both traffic grooming (single hop and multi-hop) and inverse multiplexing if they lead to lower cost solutions. Moreover, for multiple equal cost solutions, the tool must select the one using a minimum number of WDM channels.

The solution is computed based on the following parameters and constraints:

- **Input Parameters -** The tool has to be able to read from one input file several input parameters:

  1. **Network Topology and Capacity parameters -** A list of the OTN network nodes and network links (*i.e.*, pairs of nodes with a fiber between them); for each link, the associated fibre length and channel capacity (in number of $50GHz$ channels). When a link achieves its channel capacity, the tool has to try to reroute the OTUs through an alternative path.
  2. **Client Demand parameters -** A list of origin - destination node pairs; for each origin - destination pair, the number and type of client demands.
  3. **Available OTU parameters -** A list of available OTU types; for each type, its maximum reach and the costs of 3R regenerators, transponders, muxponders and inverse multiplexers.

- **3R Regenerator Placement constraints -** The 3R regenerators can only be placed in intermediate OTN nodes (*i.e.*, the algorithm does not consider solutions where 3R regenerators are placed in the middle of the fibres). A 3R regenerator must be placed in a node when the OTU optical signal has no remaining reach to get to the next node.

- **OTUs Maximum Reach constraints -** The length of an OTU path (which is the sum of the lengths of the fibres of the path) between 3R regenerators must be within the OTU maximum reach. For each intermediate node without a 3R regenerator, an equivalent reach penalty is considered to compensate the OTU optical signal degradation (this penalty value is defined in the input file).

- **Grooming constraints -** The solution must take advantage of single-hop grooming (*i.e.*, one OTU supporting lower granularity client demands between its end nodes) and multi-hop grooming (*i.e.*, a client demand groomed in more than one OTU from its source node to its destination node). In both alternatives, grooming is only possible with client demands of the same granularity. For example, it is not possible to groom client demands of 10 Gbps and 40 Gbps in a single OTU4 (of $100Gbps$).

- **Inverse Multiplexing constraints -** The solution must take into account inverse multiplexing, (*i.e.*, a client demand supported by multiple lower granularity OTUs) in a single path configuration (*i.e.*, all lower granularity OTUs must be routed through the same network path).

- **Channel Assignment constraints -** For each OTU on the solution, a single WDM channel must be assigned for each of its path components (a path component is the set of fibres of the OTU path between two consecutive 3R regenerators). The channel assignment task must also ensure that a channel is not assigned to more than one OTU on each fibre.

3.3 Shortest path algorithms based on Dijkstra

As will be seen later on, the overall algorithm requires different variants of a shortest path algorithm. This section starts by describing the basic Dijkstra shortest path algorithm and, then, three variant of higher complexity. The final variant is the one used in the overall algorithm.

Table 3.1 presents the definition of the variables used in all shortest path variants. One of the important lines of the table is the $*$ that represents a independent structure copy, as so, $*Sol_{i,j}$ and $Sol_{i,j}$ may or may not contain the same information but they have their own memory space and the same size. The G structure is a graph that contains the information of all nodes and arcs of the Network. We have also a similar structure that is a Virtual graph $Gv_{t,i,j}$. This structure has the same nodes as G but does not have fixed arcs. These arcs represent the gap[2] on already selected OTUs. When a new OTU is selected and not completely filled, a new arc is added in the Virtual Graph and when an existing OTU that becomes fully occupied with the assignment of some new client demands, the corresponding

[2]In some cases, at the multiplexing process, the client demand units are not enough to completely fill the supporting OTU. In that case, there is a "gap", which is represented in the Virtual Graph, that can be used to groom other client demand units. For example, if we assign 2 demands of $10G$ in a OTU of $40G$, we have a gap of 2 units for other $10G$ client demands.

arc is removed from the Virtual Network. At any time, the Virtual Graph $Gv_{t,i,j}$ gives the size and type of the gap on each arc. Still related with Virtual Graph, the structure $Lva_{i,j}$ has a list of the current virtual links and it is used to improve the performance of Dijkstra. Next, we have the $D_{i,j}$ vector that defines the arcs length of the network links. The $D10_{O,D}$, $D40_{O,D}$ and $D100_{O,D}$ define the number of client demand units from the origin node O to the destination node D of $10Gb/s$ type, $40Gb/s$ type and $100Gb/s$ type. The vector Arc_i, for each node i helps Dijkstra performance and defines all other network nodes such that the arc (i, j) exists (more on Section 3.6.2). Another structure is the capacity matrix $Cap_{i,j}$. This is a square matrix that defines the unused link capacity available at arc (i, j). In some of the following variants, the values of this matrix might be negative when the algorithm deals with unfeasible solutions. The $Rotu_t$ has the information of OTUs maximum distance reach.

Variable	Description
O	Origin node
D	Destination node
i, j	Arc between two nodes
n	Number of OTUs to place in the Network
t	Type of OTU
P	Length Penalty of OTUs in nodes without 3R
$*$	Copy of Structure
G	Graph
$Gv_{t,i,j}$	Virtual Graph
$Lva_{i,j}$	List of virtual arcs
$D_{i,j}$	Length of fibre between nodes i and j
$D10_{O,D}$	List of 10 Gb/s client demands
$D40_{O,D}$	List of 40 Gb/s client demands
$D100_{O,D}$	List of 100 Gb/s client demands
Arc_i	Support Vector (Arc count)
$Cap_{i,j}$	Unused Capacity Matrix
$Rotu_t$	Reach of OTU from type t
S	Dijkstra nodes finalized
cs	Dijkstra cost vector
ps	Dijkstra predecessor vector
$3R$	Dijkstra nodes with $3R$ regenerators vector
mg	Dijkstra margin of demands in the link vector
Sol	Dijkstra Solution

Table 3.1: Variable list that were used in the implementation of our Heuristic.

The remaining structures are vectors used by Dijkstra with the size of the number of network nodes, the S is used to save the information of the nodes already visited. The cs_i saves the costs associated to the best shortest path found from the origin to node i, ps_i saves the predecessor of node i in the chosen path. The $3R$ vector saves the nodes with 3R regenerators in the solution. The mg_i vector saves the lowest gap of all links in the chosen path from origin node to node i. Finally, the vector Sol stores the sequence of nodes of the selected shortest path from origin node to destination node.

3.3.1 First version

In this subsection, the first version, or base version, of the shortest path algorithm (which is the well-known Dijkstra algorithm) is described.

Algorithm 1: First Dijkstra implementation. Basis Dijkstra shortest path algorithm.

Input: G $D_{i,j}$ O D

Output: Sol

1 **for** $i = 1$ ***to*** $Nodes$ **do**

2     $cs_i \leftarrow \infty$

3     $ps_i \leftarrow null$

4     $S_i \leftarrow false$

5 $cs_O \leftarrow 0$

6 **while** $S_D = false$ **do** /* While destination node is not reached */

7     $lowest \leftarrow \infty$

8   **for** $i = 1$ ***to*** $Nodes$ **do**

9   **if** $S_i = false$ ***and*** $cs_i < lowest$ **then** /* If leads to a better cost */

10             $node \leftarrow i$

11             $lowest \leftarrow cs_i$

12     $S_{node} \leftarrow true$

13   **for** $j = Arc_{node-1}$ ***to*** Arc_{node} **do** /* Visits destination of node */

14   **if** $S_j = false$ **then**

15   **if** $cs_j < cs_{node} + D_{node,j}$ **then** /* If leads to a better cost */

16                 $cs_j \leftarrow cs_{node} + D_{node,j}$

17                 $ps_j \leftarrow node$

18 $next \leftarrow D$

19 $i \leftarrow 1$

20 $Sol_i \leftarrow next$

21 **while** $next \neq O$ **do** /* Save the Shortest Path */

22     $Sol_i = ps_{next}$

23     $next \leftarrow ps_{next}$

24     $i \leftarrow i + 1$

All versions of Dijkstra were implemented in one function $Dijkstra(input\ parameters)$ that allows it to be executed from several places and at different times. The Algorithm 1 is the basic Dijkstra shortest path algorithm and it finds a path from origin node O to destination node D with a minimum sum of the lengths of the fibres in the path. The output of the function is vector Solution Sol.

This algorithm starts by initializing the supporting structures: all costs cs are initialized with ∞, the predecessor list is initialized with *null* and the finalized list S is finalized with *false*. Then, the algorithm finds, step by step, the shortest path for an additional node. At line 5, we attribute a zero cost to the Origin node, so that it will be the first node to be finalized. The algorithm runs a loop till finalizing the destination node D. Inside the *while* loop, the next node to finalize is one that was not yet finalized. The criterion of the selection is the cost of the node, meaning that the algorithm will choose the next node already visited that provides the lowest cost. In the first cycle, the node that is chosen is the origin O because it is the only one that has the zero cost. After selecting the next finalized node, the algorithm marks the chosen node as finalized (line 12). The next step is to visit all nodes linked to the finalized one. For that, the auxiliary structure Arc_i is used in order to go directly to the network links that start at the finalized node. At this point, the algorithm updates the cost (and predecessor) of the visited nodes with the current cost (and node) if its cost is currently worse (lines 15, 16 and 17). This cycle repeats till the destination node D is finalized. After line 17, the shortest path is stored in the Sol vector. This step starts in node D (because it is easier to find the predecessor) and ends in node O: a loop finds the next node previously selected in the ps vector, and it ends when node O is reached.

3.3.2 Second version

In the second version presented here, the previous algorithm is modified such that the cost of the path is given by the number of required 3R regenerators and the network links with no spare channels are not used. In addition, the algorithm returns 1 if there is no possible shortest path. For better understanding, Algorithm 2 is presented highlighting the difference from the previous algorithm in red.

Since the reach of the path depends on the type of OTU to which the path is being selected and the penalty on nodes, the type t and the penalty P are new input parameters. Since this algorithm does not use fully occupied links, the unused capacity matrix Cap is also an input parameter.

Besides the initialization steps, the most significant differences are the following ones. First, in lines 6 to 10 the origin node O is finalized before entering the while cycle (in this node, we do not need to take into consideration the penalty P). In lines 17 to 20, if no new node can be finalized, the algorithm returns one because no path exists. In lines 22 to 31, the new cost of the visited node is the same as the cost of current finalized node if the path is inside the maximum reach (with the penalty P) or is plus 1 if a 3R regenerator has to be placed in the current finalized node. In lines 32 to 38, besides storing the shortest path, the nodes with 3R regenerators are also stored in vector $*3R$. Note that in conditions of lines 7, and 22, links are only considered if their unused channel capacity is not null. Note also that vector ds_i stores the length of the path from the last node with a 3R regenerator up to node i.

3.3.3 Third version

In the third version presented here, the previous algorithm is modified such that the algorithm returns the number of channels available in the selected shortest path and gives preference to predecessor nodes that provide the same cost and an higher number of available channels. Note that, since the cost is now given by the number of regenerators, in general, there are multiple paths with the same cost. The idea is that when finding a path for a new OTU, the path being selected on the least loaded links. In this way, a better load balanced network is obtained reducing the number of WDM channels used by the overall solution.

As before, Algorithm 3 is presented highlighting the differences from the previous algorithm in red. The most significant differences from the previous algorithm are the following

Algorithm 2: Second Dijkstra implementation. In this version, the cost of the path is given by the number of required 3R regenerators and network links with no spare channels are not used. It returns 1 if there is no possible shortest path.

Input: $G\ D_{i,j}\ O\ D\ Cap\ t\ P$
Output: $Sol\ *3R$

```
for i = 1 to Nodes do
    S_i ← false
    cs_i ← ∞        ps_i ← null
    ds_i ← ∞        3R_i ← 0
S_O ← true      ds_O ← 0      cs_O ← 0
for j = Arc_{O-1} to Arc_O do                        /* Solve the Origin (O) node */
    if D_{O,j} < Rotu_t and Cap_{O,j} > 0 then
        ps_j ← O
        ds_j ← D_{O,j}
        cs_j ← 0
while S_D = false do                   /* While destination node is not reached */
    lowest ← ∞
    for i = 1 to Nodes do
        if S_i = false and c_i <lowest then              /* If leads a better cost */
            node ← i
            lowest ← cs_i
    if node ∉ G then                            /* Return 1 if there is no link */
        return 1
    else
        S_node ← true
    for j = Arc_{node-1} to Arc_node do       /* Visits destination of the arc */
        if S_j = false and Cap_{node,j} > 0 then
            if ds_node + D_{node,j} + P < Rotu_t and cs_j > cs_node then
                ps_j ← node
                ds_j ← ds_node + D_{node,j} + P
                cs_j ← cs_node
            else if D_{node,j} < Rotu_t and cs_j > cs_node + 1 then
                ps_j ← node
                ds_j ← D_{node,j}
                cs_j ← cs_node + 1
                3R_node = true
next ← D      i ← 1      Sol_i ← next
*3R_{ps_D} ← 3R_D
while next ≠ O do                                  /* Save the Shortest Path */
    Sol_i = ps_next
    i ← i + 1
    *3R_next ← 3R_{ps_next}
    next ← ps_next
```

Algorithm 3: Third Dijkstra implementation (Part I of II). In this version, the algorithm returns the number of channels available in the selected shortest path and gives preference to predecessor nodes that provide the same cost and an higher number of available channels.

```
Input: G D_{i,j} O D P Cap t
Output: Sol *3R margin
for i = 1 to Nodes do
    cs_i ← ∞        ds_i ← ∞
    ps_i ← null     3R_i ← 0
    S ← false       mg_i ← 0
S_O ← true     ds_O ← 0     cs_O ← 0
for j = Arc_{node−1} to Arc_{node} do               /* Solve the Origin (O) node */
    if D_{O,j} < Rotu_t and Cap_{O,j} > 0 then
        ps_j ← O
        ds_j ← D_{O,j}
        cs_j ← 0
        mg_j ← Cap_{O,j}
while S_D = false do                   /* While destination node is not reached */
    lowest ← ∞      highest_mg ← 0
    for i = 1 to Nodes do
        if S_i = flase and (cs_i < lowest or (cs_i = lowest and mg_i > highest_mg))
        then
            node ← i
            lowest ← cs_i     highest_mg ← mg_i
    if node ∉ G then                          /* Return 1 if there is no link */
        return 1
    else
        S_node ← true
    for j = Arc_{node−1} to Arc_{node} do        /* Visits destination of the arc */
        if S_j = false and Cap_{node,j} > 0 then
            mg_save ← min(mg_node, Cap_{node,j})
            if ds_node + D_{node,j} + P < Rotu_t and (cs_j > cs_node or (cs_j = cs_node and
            mg_j < mg_save)) then
                ps_j ← node
                ds_j ← ds_node + D_{node,j} + P
                cs_j ← cs_node
                mg_j ← mg_save
            else if D_{node,j} < Rotu_t and (cs_j > cs_node or (cs_j = cs_node and
            mg_j < mg_save)) then
                ps_j ← node
                ds_j ← D_{node,j}
                cs_j ← cs_node + 1
                mg_j ← mg_save
                3R_node = true
```

Algorithm 3: Third Dijkstra implementation (Part II of II). In this version, the algorithm returns the number of channels available in the selected shortest path and gives preference to predecessor nodes that provide the same cost and an higher number of available channels.

$margin \leftarrow mg_D$
$*3R_{ps_D} \leftarrow 3R_D$
$next \leftarrow D$
$i \leftarrow 1$
$Sol_i \leftarrow next$
while $next \neq O$ **do** `/* Save the Shortest Path */`
    $Sol_i = ps_{next}$
    $i \leftarrow i + 1$
    $*3R_{next} \leftarrow 3R_{ps_{next}}$
    $next \leftarrow ps_{next}$

---

ones. The variable *margin* is an additional output variable where the number of available channels is returned. In the conditions of lines 15, 25 and 30, a visited node selects as its predecessor the current finalized node if it provides the same cost but an higher number of available channels. The new vector mg_i is always updated in lines 29 and 34 with the minimum number of available channels among all links from the origin node up to node i (line 24). At the end, the output variable *margin* returns the value of the vector mg at the destination node D.

3.3.4 Fourth version

Note that the previous third version is not exact, *i.e.*, it might determine a path which is not of minimum cost. This is because the decision of the predecessor based on the available channels might let the algorithm select a predecessor in a longer path, which subsequently might require more 3R regenerators. To solve this issue, whenever the shortest path algorithm is required, we run both second and third versions and select the third version solution if it is not worse than the second version solution (and select the second version solution, otherwise). Moreover, the overall algorithm also requires that a shortest path is given even if it is not feasible, *i.e.*, if it must use some links with no spare free channels. The present fourth version, the final one, incorporates these two features.

Algorithm 4 is presented using two colors. The red highlights (as in the previous cases) the differences from the previous version. As already explained, this algorithm computes two shortest path solutions, one with load balance and one without. In order to condense the algorithm description, the parts of the code only executed in the load balance solution are highlighted in blue color, while the remaining parts are executed in both solutions.

In this algorithm, a new input parameter $flag$ specifies that the path must use only links with available channels (if it is $false$) or can use all links (if it is $true$). Nevertheless, when $flag = false$, the fully occupied links are accounted with a cost of 100 (lines 16 and 21 in Part II of III) if they are in the solution. Therefore, the number of such links in the solution is always minimized.

The first option (*i.e.*, the decision of the predecessor based of the available channels) is

Algorithm 4: Fourth Dijkstra implementation (Part I of III). In this version, the algorithm ensures that the path obtained is the cheapest, and accepts an option that defines if the path can use (or cannot use) links with zero or negative capacity.

Input: $G\ D_{i,j}\ O\ D\ Cap\ P\ t\ flag$
Output: $Sol\ *3R\ margin$

for $i = 1$ ***to*** $Nodes$ **do**
  $cs_i \leftarrow \infty \quad ds_i \leftarrow \infty \quad 3R_i \leftarrow 0 \quad mg_i \leftarrow 0 \quad ps_i \leftarrow null \quad S_i \leftarrow \infty$
$S_O \leftarrow true \quad ds_O \leftarrow 0 \quad cs_O \leftarrow 0$
for $j = Arc_{O-1}$ ***to*** Arc_O **do** `/* Solve the Origin (O) node */`
  if $flag = true$ **then**
    if $D_{O,j} < Rotu_t$ **then**
      $ps_j \leftarrow O$
      $ds_j \leftarrow D_{O,j}$
      $cs_j \leftarrow 0$
      $mg_j \leftarrow Cap_{O,j}$
  else
    if $D_{O,j} < Rotu_t$ ***and*** $Cap_{O,j} > 0$ **then**
      $ps_j \leftarrow O$
      $ds_j \leftarrow D_{O,j}$
      $cs_j \leftarrow 0$
      $mg_j \leftarrow Cap_{O,j}$
while $S_D = false$ **do** `/* While destination node is not reached */`
  $lowest \leftarrow \infty \quad highest\_mg \leftarrow 0$
  for $i = 1$ ***to*** $Nodes$ **do**
    if $S_i = false$ ***and*** $(cs_i < lowest$ ***or*** $(cs_i = lowest$ ***and*** $mg_i > highest\_mg))$ **then**
      $node \leftarrow i$
      $lowest \leftarrow cs_i \quad highest\_mg \leftarrow mg_i$
  if $node \notin G$ **then** `/* Return 1 if there is no link */`
    return *1*
  else
    $S_{node} \leftarrow true$
  for $j = Arc_{node-1}$ ***to*** Arc_{node} **do** `/* Visits destination of link */`
    if $S_j = false$ ***and*** $Cap_{node,j} > 0$ **then**
      $mg\_save \leftarrow min(mg_{node}, Cap_{node,j})$
      if $ds_{node} + D_{node,j} + P < Rotu_n$ ***and*** $(cs_j > cs_{node}$ ***or*** $(cs_j = cs_{node}$ ***and*** $mg_j < mg\_save))$ **then**
        $ps_j \leftarrow node$
        $ds_j \leftarrow ds_{node} + D_{node,j} + P$
        $cs_j \leftarrow cs_{node}$
        $mg_j \leftarrow mg\_save$

Algorithm 4: Fourth Dijkstra implementation (Part II of III). In this version, the algorithm ensures that the path obtained is the cheapest, and accepts an option that defines if the path can use (or cannot use) links with zero or negative capacity.

while $S_D = false$ **do** /* While destination node is not reached */
  $\vdots$
  for $j = Arc_{node-1}$ ***to*** Arc_{node} **do** /* Visits destination of link */
    if $S_j = false$ ***and*** $Cap_{node,j} > 0$ **then**
      if $ds_{node} + D_{node,j} + P < Rotu_n$ ***and*** $(cs_j > cs_{node}$ ***or*** $(cs_j = cs_{node}$ ***and*** $mg_j < mg\_save$ $))$ **then**
        $\vdots$
      else if $D_{node,j} < Rotu_n$ ***and*** $(cs_j > cs_{node}$ ***or*** $(cs_j = cs_{node}$ ***and*** $mg_j < mg\_save$ $))$ **then**
        $ps_j \leftarrow node$
        $ds_j \leftarrow D_{node,j}$
        $cs_j \leftarrow cs_{node} + 1$
        $mg_j \leftarrow mg\_save$
        $3R_{node} = true$
    else if $S_j = false$ ***and*** $flag = true$ **then** /* Flag on */
      $mg\_save \leftarrow min(mg_{node}, Cap_{node,j})$
      if $ds_{node} + D_{node,j} + P < Rotu_n$ ***and*** $(cs_j > cs_{node} + 100$ ***or*** $(cs_j = cs_{node} + 100$ ***and*** $mg_j < mg\_save$ $))$ **then**
        $ps_j \leftarrow node$
        $ds_j \leftarrow ds_{node} + D_{node,j} + P$
        $cs_j \leftarrow cs_{node} + 100$
        $mg_j \leftarrow mg\_save$
      else if $D_{node,j} < Rotu_n$ ***and*** $(cs_j > cs_{node} + 101$ ***or*** $(cs_j = cs_{node} + 101$ ***and*** $mg_j < mg\_save$ $))$ **then**
        $ps_j \leftarrow node$
        $ds_j \leftarrow D_{node,j}$
        $cs_j \leftarrow cs_{node} + 101$
        $mg_j \leftarrow mg\_save$
        $3R_{node} = true$

$mg\_temp \leftarrow mg_D$
$*3R_{ps_D} \leftarrow 3R_D$
$next \leftarrow D$ $i \leftarrow 1$
$Sol_i \leftarrow next$
while $next \neq O$ **do** /* Save the Shortest Path */
  $Sol_i \leftarrow ps_{next}$
  $*3R_{next} \leftarrow 3R_{ps_{next}}$
  $next \leftarrow ps_{next}$
  $i \leftarrow i + 1$

Algorithm 4: Fourth Dijkstra implementation (Part III of III). In this version, the algorithm ensures that the path obtained is the cheapest, and accepts an option that defines if the path can use (or cannot use) links with zero or negative capacity.

1 Rerun from line 1 of Part (I of III) till line 25 of Part (II of III) without executing load balance code highlighted in (Blue) color
2 **if** $*3R > 3R$ **then** `/* Choose the solution that has less 3R */`
3 $\quad margin \leftarrow mg_D$
4 $\quad *3R_{ps_D} \leftarrow 3R_D$
5 $\quad next \leftarrow D \qquad i \leftarrow 1$
6 $\quad Sol_i \leftarrow next$
7 $\quad$ **while** $next \neq O$ **do** `/* Save the Shortest Path */`
8 $\quad\quad Sol_i \leftarrow ps_{next}$
9 $\quad\quad *3R_{next} \leftarrow 3R_{ps_{next}}$
10 $\quad\quad next \leftarrow ps_{next}$
11 $\quad\quad i \leftarrow i + 1$
12 **else**
13 $\quad margin \leftarrow mg\_temp$

firstly executed. The path obtained is then saved in the output structure (lines 26 to 34 of Part II) together with the margin value of the path. The first line of Part III represents the second run where the previous code from line 1 of Part I till line 25 of Part II is run without load balance code highlighted in blue color. Afterwards, a cost comparison is made in line 2 in Part III. If the new found cost is lower, the second path is stored in the output structure (lines 2 to 11 in Part III). Otherwise, it just updates the output margin variable of the first path (line 13 in Part III).

3.3.5 Dijkstra Virtual Graph version

In the Virtual Graph version, the previous first version (Algorithm 1) is modified to deal run in the virtual graph Gv. It aims to compute a path with a minimum number of hops and it returns the margin provided by such path (necessary to know how many client demands can be groomed through that path). Algorithm 5 is presented highlighting the difference from the first algorithm in red color. Here, the cost of a path is its number of links. The output of the function is vector Sol and variable $margin$. This last variable is an additional output variable where the number of available channels is returned. If there is no possible shortest path, the algorithm returns 1 (lines 13 and 14). The search for the virtual links from origin to destination is done in lines 17, 18 and 24. Then, the gap type verification is done (line 19), followed by the cost and margin comparison (line 20). In this version, the links chosen are those with the larger number of gaps of type t. At the end, the margin value is the minimum value of the link gaps (lines 20, 26, 32, 36 and 37).

Algorithm 5: Virtual Graph version of Dijkstra implementation. In this version, the algorithm returns a path with a minimum number of hops, if it exists, and the margin provided by such path.

```
Input: Gv Lav D_{i,j} O D t
Output: Sol margin
for i = 1 to Nodes do
    cs_i ← ∞
    ps_i ← null
    mg_i ← −∞
    S_i ← ∞
cs_O ← 0
while S_D = false do                          /* While destination node is not reached */
    lowest ← ∞
    for i = 1 to Nodes do
        if S_i = false and cs_i <lowest then   /* If leads to a better cost */
            node ← i
            lowest ← cs_i
    if node ∉ G then                           /* Return 1 if there is no link */
        return 1
    else
        S_node ← true
    for j = 1 to j ∈ Lva do                    /* Visits all virtual arcs */
        if Lva_{node,j} = true then
            if S_j = false and Gv_{t,node,j} > 0 then
                if cs_j > cs_node and mg_j < Gv_{t,node,j} then
                    cs_j ← cs_node + 1
                    ps_j ← node
                    mg_j ← Gv_{t,j,node}
        else if Lva_{j,node} = true then
            if S_j = false and Gv_{t,j,node} > 0 then
                if cs_j > cs_node and mg_j < Gv_{t,j,node} then
                    cs_j ← cs_node + 1
                    ps_j ← node
                    mg_j ← Gv_{t,j,node}
next ← D        i ← 1
Sol_i ← next
margin ← ∞
while next ≠ O do                             /* Save the Shortest Path */
    Sol_i = ps_next
    next ← ps_next
    if mg_next < margin then
        margin ← mg_next
    i ← i + 1
```

3.4 Channel Assignment

As will be seen later, the algorithm first computes a minimum cost solution where the routing paths of each OTU are only computed in order to be inside the capacity (in number of channels) of each fiber link. Then, the channel assignment is conducted. The channel assignment aims to assign a channel number to the lightpaths of each OTU, which must follow the usual continuity constraints, *i.e.*, the channel number must be the same in all fiber links without intermediate 3R regenerators. Therefore, we might have a solution that cannot be channel assigned. Consider the example shown in Figure 3.3 based on a triangular network with 3 nodes and 3 links where the capacity of all links is 2 channels. Clearly, the routing solution is feasible (each link supports two OTUs) but the channel assignment is infeasible since we need three channels to have a channel assignment solution: first, we assign the channel number 1 to $1 \rightarrow 2$ OTU path and then the channel number 2 to $3 \rightarrow 1$ OTU path. For the $2 \rightarrow 3$ OTN path, we cannot use neither channel number 1 because it is already assigned on link $1 \rightarrow 3$ nor channel number 2 because it is already assigned on link $2 \rightarrow 1$. To have a feasible assignment, we must have a third available channel.

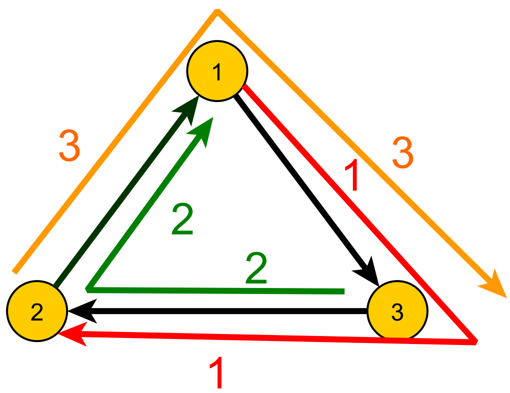

Figure 3.3: Channel assignment example that requires 3 channels when the maximum link capacity is 2.

The channel assignment function accepts as input a solution whose routing paths are within the channel capacity of all links. For the WDM channel assignment, we have to consider that when a 3R regenerator is used in an intermediate node of an OTU, it enables wavelength conversion. Therefore, different WDM channels can be assigned to the same OTU and the continuity constraints must be guaranteed only in the fiber links of the OTU without intermediate 3R regenerators.

The channel assignment task can be a process that requires considerable time. The final channel assignment process is shown in Figure 3.4.

The first step is to decompose the path in the 3R regenerators points, if they exist, creating and storing these new paths in a supporting structure. Consider the example shown in Figure 3.4. In this example, we have one path with 6 regenerators (blue color squares) and, below, is its decomposition in 7 elementary paths. The second step is the process of sorting, in non-increasing order, the elementary paths, which uses two sorting criteria: i) number of links of the elementary path; ii) among all paths with the same number of links, number of channels

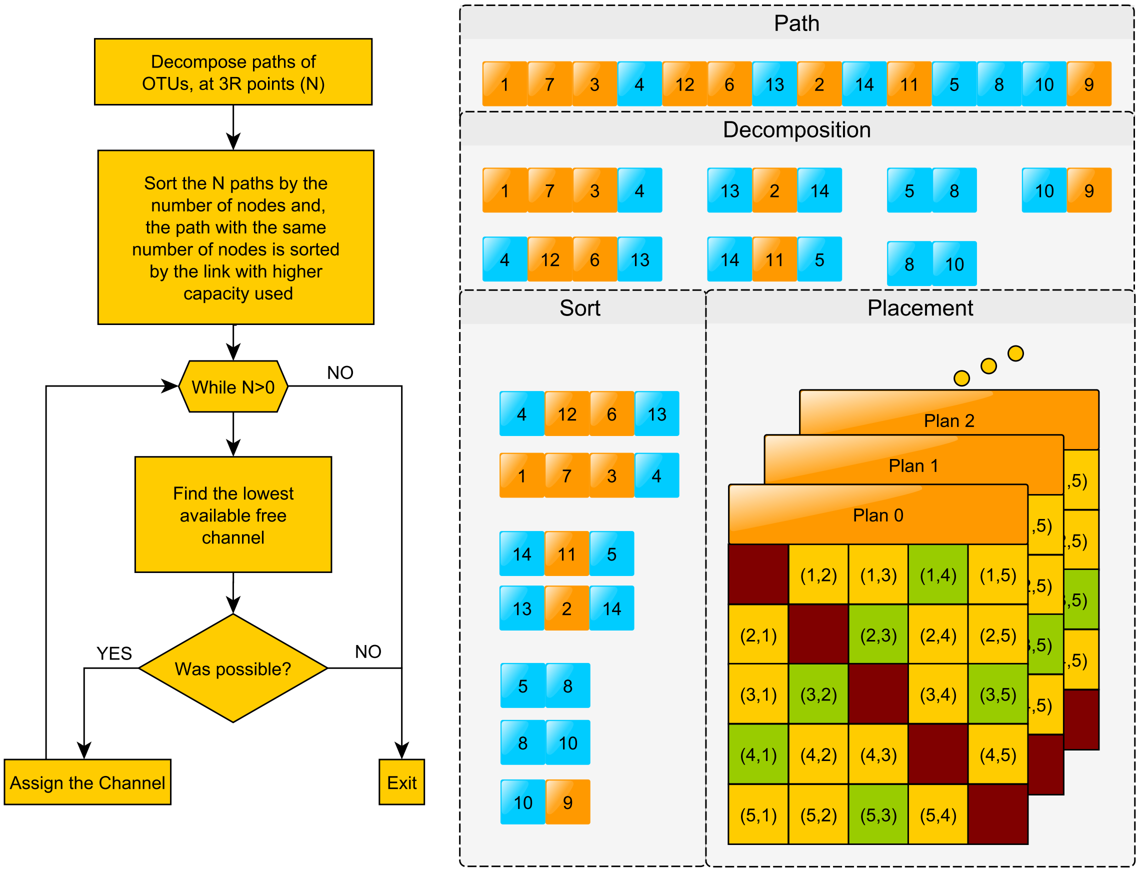

Figure 3.4: Diagram of the channel assignment process and an illustrative example.

of the most congested link. The sort process is explained, in detail, in Section 3.6.3. After this process, the list becomes similar to the one present in the *Sort* box in Figure 3.4. The last step in the channel assignment uses one three-dimensional $3D$ structure (details will be explained in the Section 3.6.2). The $3D$ structure is also illustrated in the *Placement* box in Figure 3.4. In Plan 0 of this structure, we store the number of channels already assigned to each fiber link. For each possible channel number x, Plan x stores the OTU that has been assigned with channel number x.

In the assignment process, we start from the top of the elementary path list. For each elementary path, we search in the $3D$ structure for the lowest free channel number in all fiber links of the path and assign such channel number (updating the $3D$ structure accordingly). Note that this process can become a heavy computational process. For example, in the Figure 3.4 example, we start by finding a channel for the first path that has three fiber links $4 \rightarrow 12 \rightarrow 6 \rightarrow 13$. First, the $3D$ structure Plan 1 is verified to see if channel number 1 is not used in the entries $4 \rightarrow 12$, $12 \rightarrow 6$ and $6 \rightarrow 13$. If not, channel 1 is assigned. If yes, the same check is then done in Plan 2. This process ends when an available channel is assigned. If no available channel is find, the channel assignment fails and the solution is considered invalid.

3.5 Multi-Thread Multi-Start Local Search Algorithm

In this section, the Multi-Thread Multi-Start Local Search Algorithm is presented, which uses the meta-heuristic explained in Section 3.1, and is in accordance with the problem definition constraints defined in Section 3.2. First, the global algorithm is presented as well as the threads implementations. Then, the Greedy algorithm and the Local Search algorithm are described together with how the solutions are handled.

3.5.1 Global Algorithm

In order to run the tool that executes the optimization algorithm, the following command must be executed on a **Command Prompt** window:

tese.exe name_of_input_file.data execution_time Number_of_threads

The three input parameters are the input file specifying the problem input parameters, the execution time that is used as stopping criteria and the number of threads to be launched. Appendix A presents an example of a valid input file. The first line of the input file must contain the number of nodes and links of the network. Then, the network links must be listed such that the first column is the origin node, the second column is the destination node, the third column is the length between the nodes and, finally, the fourth column is the link capacity in number of channels. Then, the client demands must be list such that the first column is the origin node, the second column is the destination node and the following three column are the number of units of $10Gb/s$, $40Gb/s$ and $100Gb/s$ client demands, respectively. Then, information regarding the possible OTU types must be listed. Each line specifies the OTU type in the first column, then, the used width spectrum, the 3R regenerators costs, the maximum reach in km, and then the costs of transponders, muxponders for the lower granularity, muxponders for the second lower granularity, and finally the costs of the inverse muxponders. Note that we ignore the lines with width spectrum different of $50GHz$ since this work deals only with fix-gridOTN solutions. The values used on this work are based on the reference costs recently proposed [13] in a Multilayer Cost Model for Metro/Core networks. The last information of the input file is the penalty applied in every intermediate node without 3R regeneration, due to the attenuation of $0.64dB$ per each WSS, that then translates into a reach penalty directly proportional to the number of WSS and to reach penalty km. The estimated reach penalty is $80km$ per WSS, and we consider that a signal bypass in a node traverses two WSS[14]. So, we consider a node penalty of $160km$.

The tool as two options to launch threads, with and without shared memory as represented in Figure 3.5. The left side of figure shows the launching process without shared memory. Here, every thread creates its own memory space for the solution, where they save its incumbent solution. When all threads finish the search, the main program computes the best overall solution among all incumbent solutions. The right side of Figure 3.5 shows the shared memory implementation. Here, the main program allocates space for the overall best solution, and passes a pointer to the shared memory location to all threads. Every time that a thread generates a better solution, a comparison is made with the present solution in the shared memory. If the solution is better, then the thread saves it in the shared memory. Otherwise, it gets the current solution in the shared memory and returns to its normal execution. The access to the shared memory is made through a semaphore, that only allows one thread to access the memory area at each time. This strategy is a way to avoid problems

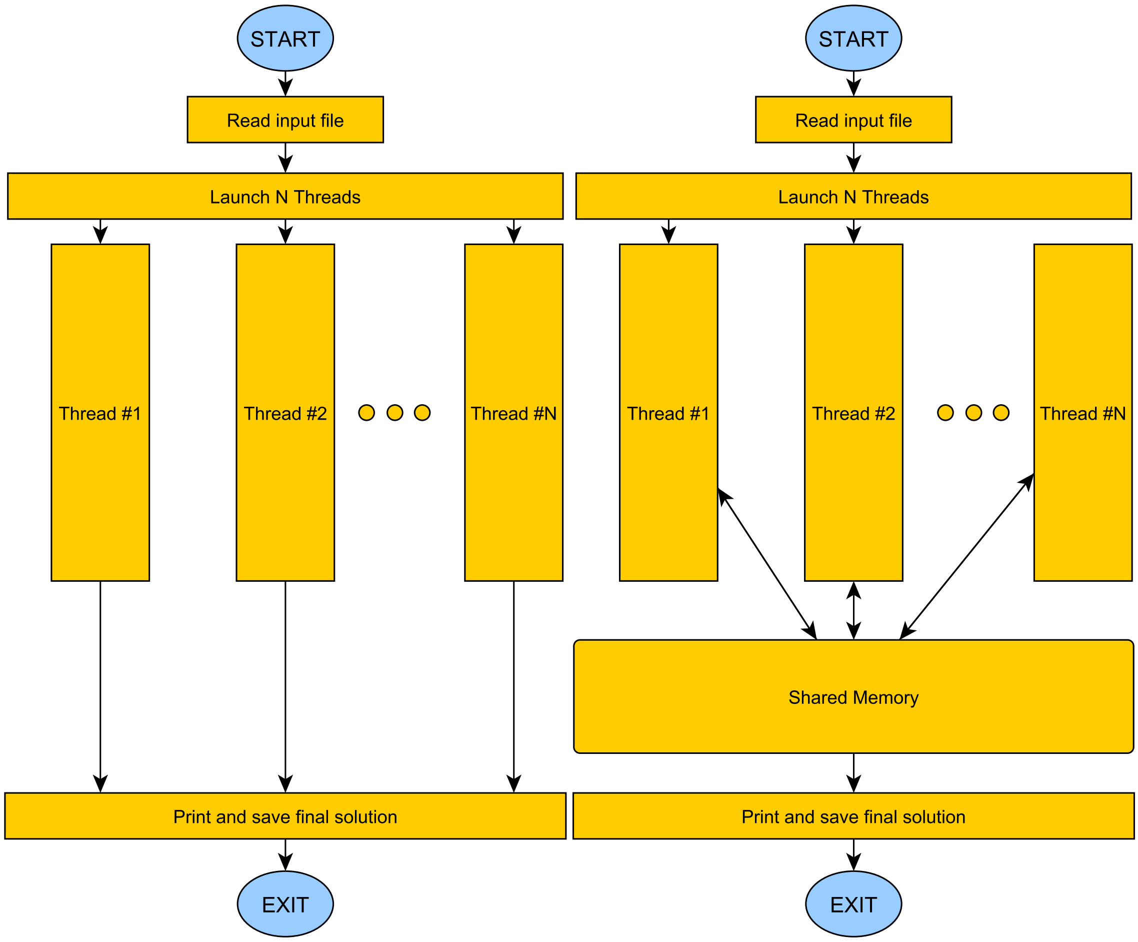

Figure 3.5: Illustrative schematic of the two approaches to the implementation of the thread launching.

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of multiple access, although, introducing a delay in the execution of the threads. When all threads finish the search, the main program simply accesses the shared memory space and retrieves the stored solution. More details on this process are given in the section 3.5.2 entitled "Multi-Thread Approach".

When the tool is initiated, the first step is to read the input file information, to create all necessary structures and to launch the appropriate threads. The pointers of the initial created structures are passed to the threads, accordingly with the type of communication between then (Figure 3.5). On each thread, a Multi-Start Local Search algorithm is run. At the beginning of each start, a Greedy algorithm generates the first solutions (more information in Section 3.5.3). Then, this solution is given to the Local Search algorithm that finds all neighbour solutions and moves for the best one and, then repeats the process until the best neighbour solution does not improve the current solution (more information in Section 3.5.4). The best solution found in the local search will be compare with the thread incumbent, and stored it if it is better. After all threads finish their execution, the tool saves the best found solution in one output file and shows in the screen some information of the best found solution.

The information displayed by the tool at the end is similar to the one present in Appendix B. The first part shows the final capacity matrix that allows the analysis of the used capacity of all fiber links. Then, the demands information is presented, in which the first column is the demand index, the next two columns are the origin and destination of the demand, then, the units of the demands granularity's that can be $10Gb/s$, $40Gb/s$ and $100Gb/s$. The next column represents the OTU sets used to route the demand through the network and the next values are: first the index of the OTU set, second the number of units that this OTU set carries. An OTU set is a set of OTUs of the same type between the same pair of nodes and with the same routing path. For eaxmple, the first row shown in Appendix B specifies that the 15 units of $10Gb/s$, from node 9 to 14, are all routed through the OTU set with the index number 46. Note that we can have cases where the demand of an origin destination pair is routed through more than one OTU set. Consider the example of line 3. Here, the number of units is 26 where 2 are routed through two OTU sets, the ones with index 55 and 50 (therefore, using multi-hop grooming) and 24 are routed through one OTU set with index 74.

Then, the tool displays the list of OTU sets of the solution. As before, the first three columns represent the index, origin and destination nodes (the first row displays the number of OTU sets of the list). The column $Ty1$ specifies the type of the OTU and the column $Ty2$ specifies the granularity of the transported demand. The next column shows the gaps (*i.e.*, the number of unused entries that might be higher than 0 in OTUs that are grooming lower granularity demands), the following column is the number of OTU of the OTU set. The following two column shows the number of nodes of the path, and the number of 3R regenerators needed. The following numbers are the routing path and the nodes that have the regenerators. At the end of the line (after the || symbol), the number of indexes and a list of the demand indexes supported by the OTU set is shown.

After the list of OTU sets, the tool displays Plan 0 of the tree-dimensional structure of the assigned channels, which specifies the number of channels assigned to each fiber link. Finally, the tool displays different information parameters on the algorithm execution and the best found solution.

3.5.2 Multi-Thread Approach

To improve the performance of the optimization tool, the implementation of threads allows to extract the maximum capacity of the computational platform. As mentioned earlier, two thread strategies were implemented, with shared memory and without shared memory. The implementation without shared memory has the following features:

- **Memory -** Each thread has its own memory space for the incumbent solution.
- **Information -** In this implementation, the incumbent solution's information is not shared between threads and, therefore, every time that each thread finds a potentially better solution, it runs the channel assignment task, losing performance with this process.

In the implementation with shared memory has the following features:

- **Memory -** Each thread, when finds a solution better than a previous incumbent solution, it access the shared memory to verify if a better incumbent solution exists.

- **Semaphores -** To access the shared memory, every thread has to wait for the semaphore. This can be a performance issue, mainly when the number of thread increases.

- **Saving time -** When a thread goes to the shared memory, if a better global incumbent solution exists, the channel assignment task is not run and, therefore, this feature reduces the number of times this computational demanding task is run. Moreover, the better global incumbent solution values (cost and maximum assigned channel) are always stored locally by the thread. Therefore, a new access to the shared memory is required only when the thread finds a new potentially better solution.

Note that through the next pages a "better/worse solution" will be mentioned. The declaration of a solution as being better than another is defined using three terms of comparison:

1. **Cost -** When the solution is feasible, the cost is the most important factor and the aim is always to try to achieve one cheaper solution.

2. **Channel assigned -** This is a secondary factor. If we have two solutions with the same cost, the best solution is the one that has a lower maximum assigned channel.

3. **Feasible -** Independently of the cost, the optimization tool will always choose one feasible solution when compared with an unfeasible. When comparing two unfeasible solutions, we choose the one that has a lower unfeasible degree (which is given by the sum, for all fiber links, of the number of channels above the link capacity used by the solution).

Figure 3.6 illustrates the diagram of a single thread with shared memory execution. The start block represents the creation of the thread in the main program. Then, the thread has to initialize all the structures and variables needed for its execution. Then, the thread enters in a *while* cycle that ends by time. Inside this cycle, it runs the Greedy and Local Search steps. Then, the solution generated by the Local Search is compared with the thread incumbent. If the Local Search solution is worse, the cycle ends. Otherwise, the solution is compared with the solution in the shared memory. Here, if the solution is worse, the thread incumbent solution is replaced by the one present in the shared memory and the cycle ends. If not,the thread runs the channel assignment tasks. Note that, in case of unfeasible solutions, it saves the solution in the shared memory without the need to run channel assignment task. Finally, if the channel assignment task does not fail (*i.e.*, if a proper set of channels are successfully assigned to the routing solution coming from the Local Search step), this solution is saved in the shared memory and the cycle ends. Otherwise, before the end of the cycle, the thread incumbent solution is replaced by the one present in the shared memory.

Figure 3.6 also illustrates the diagram of a single thread without shared memory execution. In this case, the different behaviour is defined by the Orange arrows. When the Local Search solution is better than the thread best solution, the thread goes directly to the feasibility verification. Then, if the solution is feasible, the thread runs the channel assignment task. Otherwise, it saves the solution in the thread incumbent without running the channel assignment task. If the channel assignment task is successful, the thread saves the solution in the thread incumbent. Otherwise, the solution is discarded.

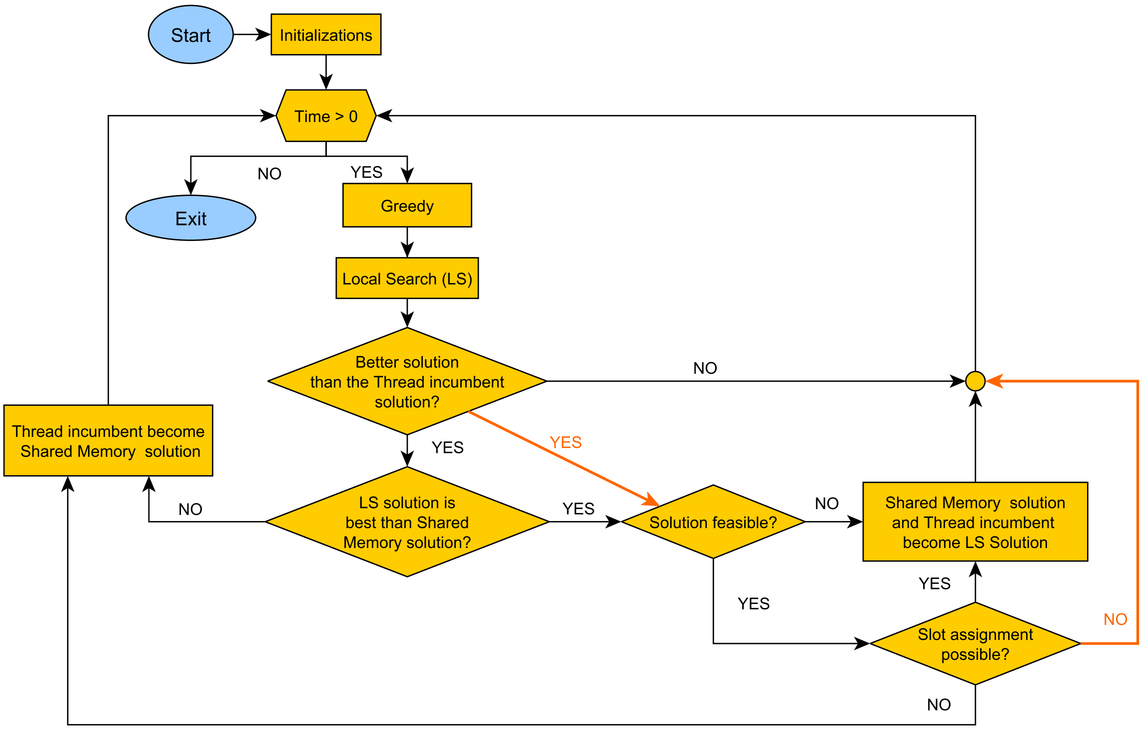

Figure 3.6: Diagram illustration of one thread execution with shared memory (ignoring orange arrows).

3.5.3 Greedy Solutions

The Greedy algorithm generates a random solution each time it is run. This algorithm uses the fourth version of Shortest Path implementation, as described in Section 3.3.4, and the Dijkstra Virtual Graph version, as described in Section 3.3.5.

Figure 3.7 illustrates the Greedy algorithm. It starts by cleaning the logical graph structure and, then, it sorts randomly the Demands. Here, we guaranty the random start in the solution space as explained in 3.1. This step is necessary to generate different initial solutions among the different algorithm cycles. Moreover, to guarantee different random solutions between different threads, the implemented solution forces the threads to create "random seeds" using its own identification number, forcing different seeds between threads.

The next step of the algorithm is a cycle that routes each demand by the previous generated order. Here, the algorithm first routes the $100Gb/s$ demands, then the $40Gb/s$ demands and finally the $10Gb/s$ demands. In this way, the lower granularity demands can use the gaps left by the routing of the higher granularity demands, potentially saving costs and/or increasing network efficiency. For each demand, the algorithm tries to route as much demand units as possible in the logical graph in a direct path. If that path is not available or if it is not possible to route the entire demands units, the algorithm uses the Dijkstra Virtual Graph version to route the remaining demand units by multiple hop paths in the virtual graph. If all demand units are routed in the virtual graph, it goes to the next demand. Otherwise, it creates the necessary OTUs to route the remaining units. It does this operation computing the minimum cost set of OTUs. To reach this minimum cost set, the algorithm runs the

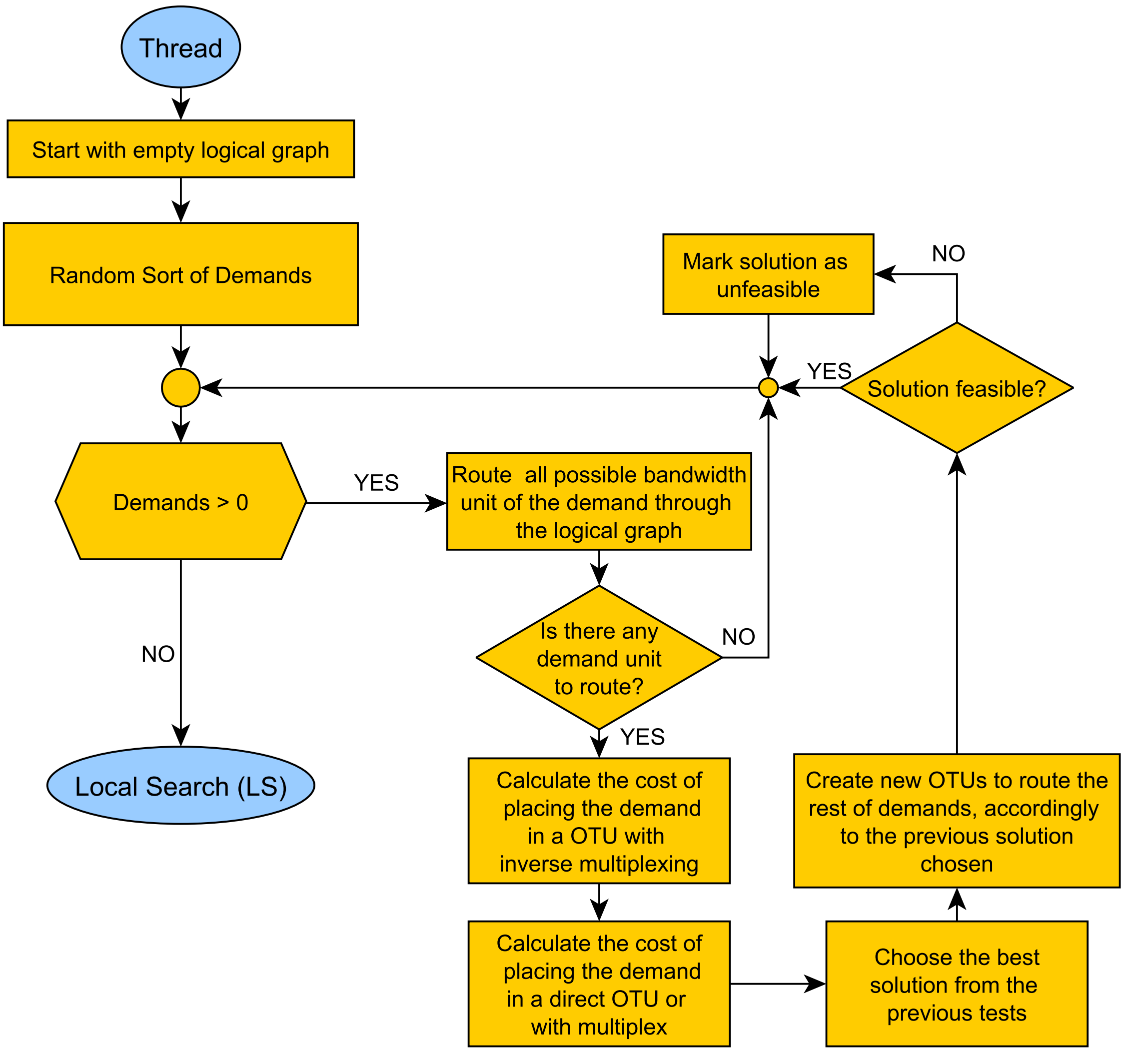

Figure 3.7: Diagram of greedy algorithm, for the generation of initial random solutions.

Shortest Path algorithm to compute the cost of the following cases (if available):

- **Inverse Multiplexing -** Route each demand unit in a lower granularity OTU (this is only possible when we are routing demand units of $100Gb/s$ on $40Gb/s$ OTUs).
- **Same OTU type -** Route each demand unit in an OTU type of the same granularity (there are two options: $100Gb/s$ on $100Gb/s$ OTU and $40Gb/s$ on $40Gb/s$ OTU).
- **First order Multiplexing -** Route the demand units in the next higher granularity OTU (there are two options: $10Gb/s$ on $40Gb/s$ OTU and $40Gb/s$ on $100Gb/s$ OTU).
- **Second order Multiplexing -** Route the demand units in the next to the next higher granularity OTU (this is only possible when we are routing demand units of $10Gb/s$ on $100Gb/s$ OTUs).

At the end, the algorithm selects the minimum cost option. The next step, shown in Figure 3.7, is the creation of the OTUs selected in the previous step. Then, the algorithm analyses if the status of the solution was changed (from feasible to unfeasible). Note that this only happens when all routing cases (inverse multiplexing, direct route and multiplexing) use a path with at least one link without any free capacity. If the solution become unfeasible that cannot become feasible again. This process repeats until all demands were routed.

3.5.4 Local Search

The Local Search is an algorithm that takes an initial solution and tries to improve it by moving iteratively to the best neighbour solution. The diagram corresponding to the Local Search process is illustrated in Figure 3.8.

This algorithm starts with the solution provided by the Greedy Algorithm (shown in Section 3.5.3). So, the first step is to create a copy of the given solution. Note that the initial solution (coming from the Greedy algorithm) can be either unfeasible or feasible. The algorithm behaves differently in the two cases. If the initial solution is feasible, the Local Solution focus on finding the neighbour solution with the lower cost or with equal cost and lower assigned channel. Otherwise (*i.e.*, if the solution is unfeasible), the algorithm first tries to turn the solution feasible by lowering the unfeasibility degree, even if that implies increasing the cost value.

The set of neighbour solutions is given by all solutions resulting from freeing one OTU and rerouting the affected client demands. Figure 3.8 shows that the current solution is first checked. If the solution is feasible, the set of OTUs selected to process the neighbour solutions is the list of all multiplexed OTUs (its number is n). If the solution is unfeasible, the set of OTUs selected to process the neighbour solutions is the list of all OTUs that use the saturated links (its number is n). After the creation of the OTU neighbour list, the Local Search algorithm enters in a cycle that represents the n OTUs previously computed. On each step of this cycle, the algorithm reloads the current solution. Then, it removes the client demands using the selected OTU. The next step is to reroute them, one by one (here, we use the same cycle as in the Greedy Algorithm). It enters in a *while* cycle until al the removed demands are routed again. First in this cycle, we try to route the demand units in the logical graph. If there are units of the demand left, we compute the minimum cost set of OTUs to route the remaining demand units.

At the end of this cycle we have created a new neighbour solution, and so, we have to compare the costs or unfeasible degree, with the current solution or with the previous best neighbour solution found. After this decision, and at the end of the n creation of the neighbour solutions, the Local Search analyses if the best neighbour solution is better than the current one. If yes, it is saved as the current solution and the outer *while* cycle is repeated. Otherwise, (*i.e.*, if the Local Search just found a neighbour solution that is worse or equal to the current one), it ends the execution delivering to the thread process the local minimum solution found.

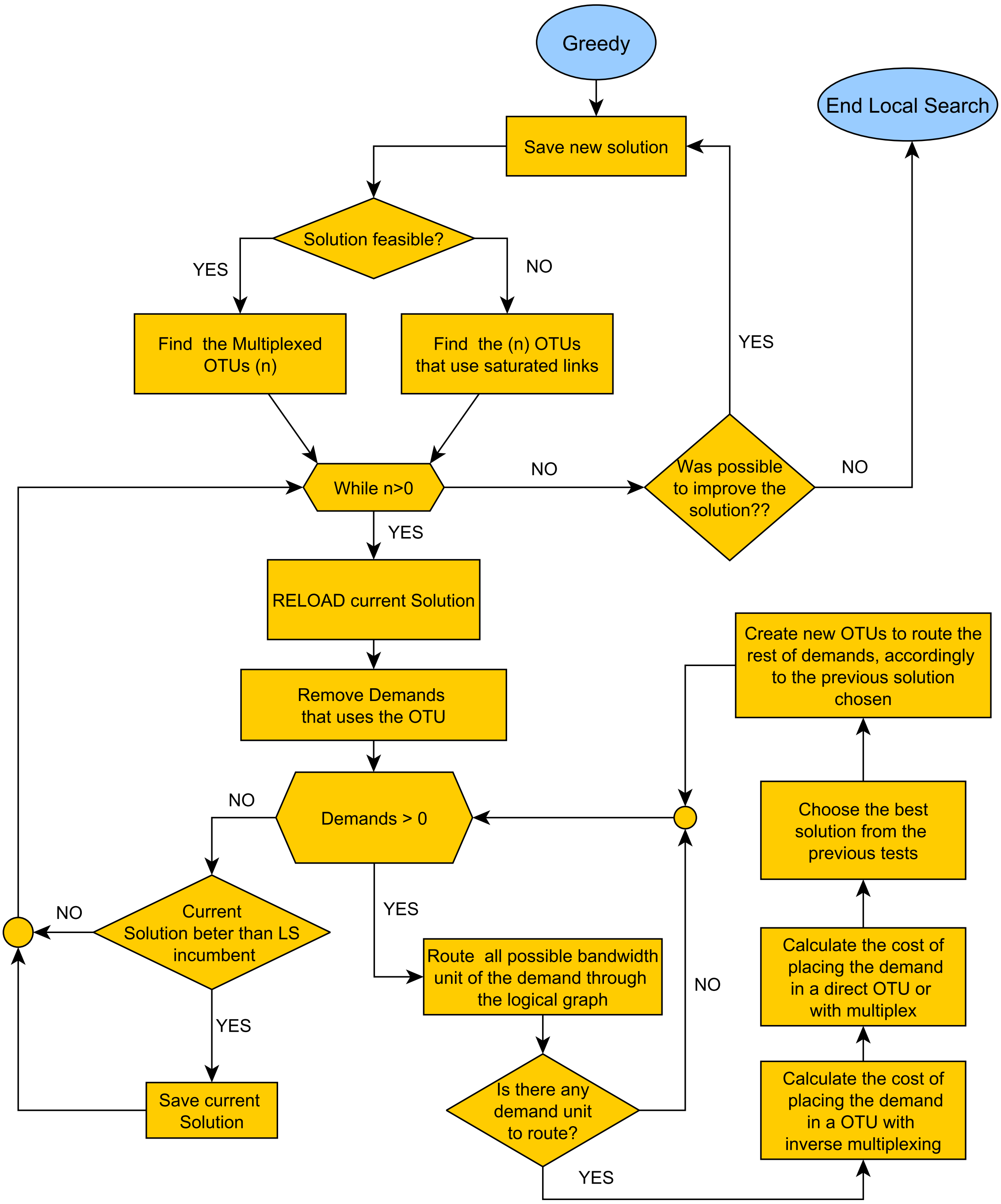

Figure 3.8: Local Search diagram illustration.

3.6 Optimization Decisions

In order to improve the overall optimizations of the tool, it is important to describe some code decisions that led to the final implementation and that had impact in the performance results.

3.6.1 Memory

The memory was a very important issue in the implementation. This was one of the first concerns in order to make the program efficient and because there are several ways to work with memory in C.

It is common to address a matrix by using i, j to reference rows and columns, for example $matrix[i][j] = 0$. This process has the disadvantage of, when we reserve the space with *calloc* function, the allocated memory may not be contiguous.

The memory handling, in the tool, initiates with certain minimal size for every structure that are directly related with some specifications of the network. Yet, for preventing memory waste when one structure becomes almost full we resort to *realloc()* function. This function is not confined to increase the matrix / vector size, it cant simply add the required space contiguously to the original vector by changing the original vector with the new required space to a new memory location.

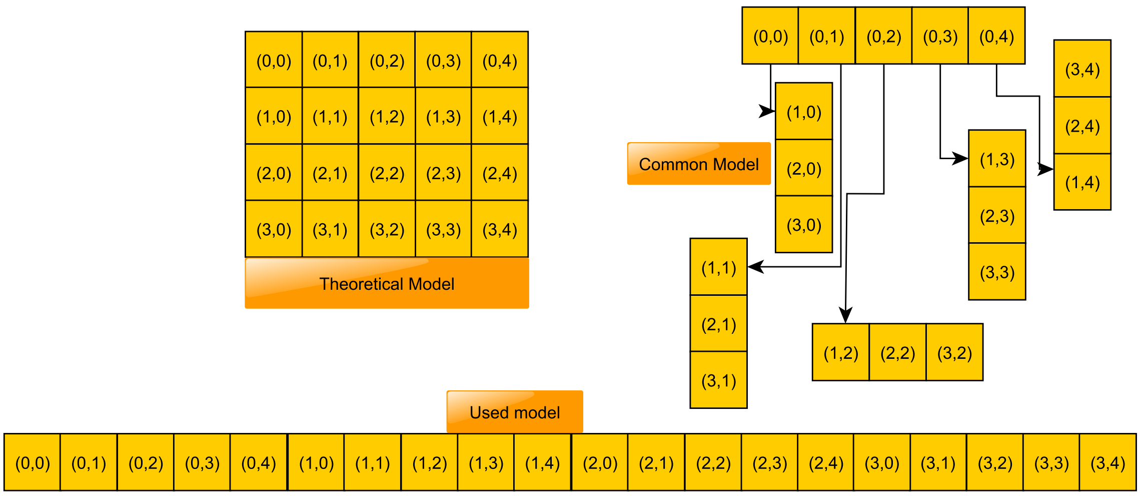

Figure 3.9: Illustration of possible memory allocation.

As shown in Figure 3.9, when we use *calloc* function to allocate memory, we idealize the theoretical model, thinking that lines and row are contiguous and next to each others (Theoretical Model). However, the memory reservation in C first allocates space to the first line and then for every column. This process makes the reserved memory to become scattered through memory. One hypothetical example is shown at the right of Figure 3.9. In the developed tool, we do not use matrices in this way. We first compute the number of positions that the structure needs and we allocate one vector of that size. Then, we use a equation that allows us to get the appropriate position: for example, replacing $matrix[i][j] = 0$ and using $matrix[nRow \times i + j] = 0$ strategy. In this way, we can reserve the memory space in a

N of elements	Time 1	Time2	Time3	Relation
10000	0.004	0.122	0.102	30.500
100000	0.046	0.968	0.841	21.043
1000000	0.997	8.840	7.764	8.867
10000000	10.655	87.546	76.968	8.216
100000000	108.815	886.829	799.349	8.150

Table 3.2: Final values of elapsed time, in the 1000 copies process, of different matrices structures.

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contiguously way as shown at bottom of Figure 3.9 (Used model). This has two immediate advantages: (i) if we need to copy the matrix structure or reset all elements, we can use *memcpy*() or *memset*() and (ii) we gain execution speed as shown in Table 3.2. This table displays the results of one test speed done to see the possible gains between the two methods. For this test, we create two types of matrices, $matrix[i][j]$ and $matrix[nRow \times i + j]$, and we copy them 1000 times, saving the elapsed time used in this action. The first column in Table 3.2, shows the total number of elements of the matrix (*i.e.*, if we have a square matrix 5×5 the total elements is obviously 25). The column labelled *Time 1* shows the time elapsed, in the copy process, using $marix[nRow \times i + j]$ matrix type and *memcpy*() function. The column labelled *Time 2* shows the time elapsed, in the copy process, using $matrix[i][j]$ matrix type and copying element by element. Finally, the column labelled *Time 3* shows the time elapsed, in the copy process, using $marix[nRow \times i + j]$ matrix type and copying element by element. The last column shows the gain between the column *Time 1* and *Time 2*.

Comparing the columns *Time 2* and *Time 3* we can see that, the use of contiguous memory already improves the performance, when the copy is made element by element. Analysing the *Time 1*, *Time 2* and the *Relation* column, we see significant gains. For matrices with higher elements number the gain tends to the factor 8. This factor increases with the decrease of the number of elements. This behaviour appear because the reduce of elements also reduce the number of bits and, the CPU has to deal with a lower number of data blocks and so, improving the speed of *memcpy*().

3.6.2 Structures

A significant part of the base structures are created while reading the input file. While reading the arcs of the network, we create one structure that will help Dijkstra performance. In this process, the information of the number of links that leave a certain node is stored. One example is shown in the second line of Table 3.3, *i.e.* in the table, 4 arcs leave the node number 9. Then, to obtain the third line of the table it is needed to: (i)short the arcs from the smallest to the biggest node number and then, in the same origin node, from the smallest to the biggest destination node (this way all the arks have a index including the 0 index), (ii) add the current number, of leaving arcs, to the previous number. For example, to obtain the number for the first node we do $2 + 0 = 0$, for the second $2 + 3 = 5$, third $5 + 3 = 8$, and so one. This numbers will be related with the indices of the arc the have the Origin node number equal to the number present in the first line of the mentioned table. With this structure, Dijkstra algorithm does not have to analyse every arc of the network looking for the links that start with the current node, neither have to go to the end of the list

i	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
n of arcs	0	2	3	3	3	3	3	2	2	4	3	3	4	2	3
Arc_i	0	2	5	8	11	14	17	19	21	25	28	31	35	37	40

Table 3.3: Structure for improvement of Dijkstra algorithm performance Arc_i

not knowing if there are another unprocessed arc. Another example is, if Dijkstra want to analyse all arcs originating from node number 1 he just see the index number given by arc_0 till arc_1 (processing the arcs with the index number 0 and 1), if it was the node 10 he see the index given by arc_9 till arc_{10} (processing the arcs with the index number 25, 26 and 27), and so on.

Another structure created to help the performance and group information is the structure represented in Figure 3.10. This structure is a three-dimensional matrix to save information regarding Channel Assignment. This structure is a square matrix that every element is a

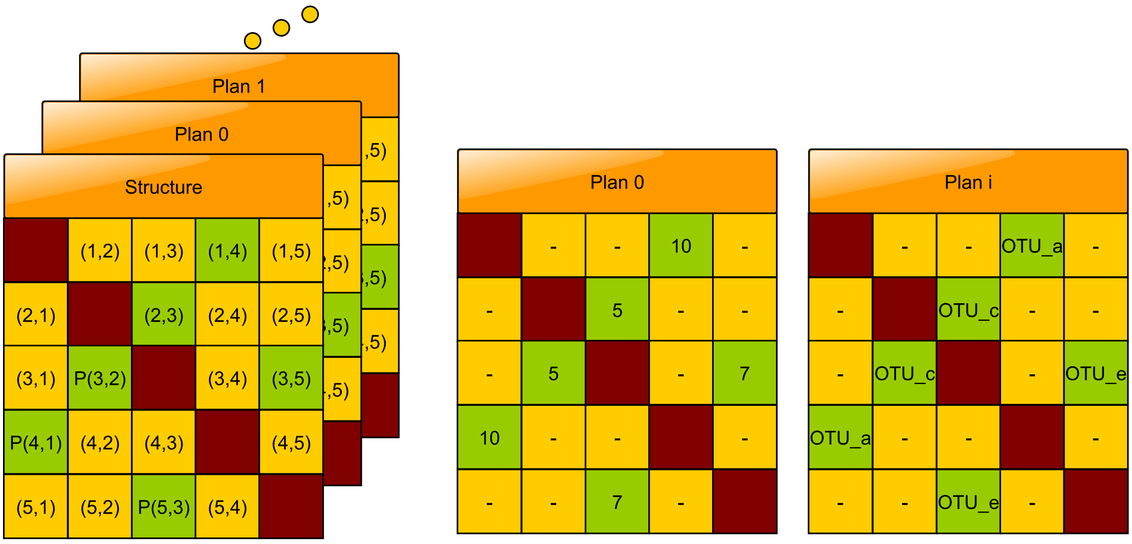

Figure 3.10: Three-dimensional structure illustration, used for stored the assignment of the channel.

vector with size of link capacity plus one, read from input file. In order to save memory we just create one vector for link, in other words, we can address a link in to way $1 \rightarrow 2$ or $2 \rightarrow 1$, but in this structure whichever way we address the link results at the same memory space. So, to create this structure we create a square matrix ($nodes \times nodes$), then we only create the refereed vector at the upper triangular matrix, creating a pointer to that vector in the lower triangular matrix, as sown at the left Figure 3.10. We also can see that the main diagonal is marked at red , and green shows the elements that represents a link. Looking at lower triangular matrix we see $P(i, j)$, these are pointers to the vectors present in (i, j) element. Looking at this structure as a group of square matrices superimposed upon plans, the first plan $Plan\ 0$ is a counter of the channels already assigned. Then, the rest of the plans (x) have information about the OTU that the (x) channel was assign. This three-dimensional matrix referred as $OC_{i,j}[k]$, is addressed in C using the method $marix[nodes \times i + j][k]$. This is a important way to address the structure because we use the implemented functions offered in C library's, without loosing performance and extra effort to create a new way to use a $3D$ matrix (originally thought $matrix[i][j][k]$).

3.6.3 Sort for channel assignment

Here we will explain, in more detail, the sort of the path list in the channel assignment process. The first step towards a optimized sort process, is having a well organized structure as presented in the Table 3.4. The first column is the index of the lines. The column named *#nodes* shows the number of nodes of the path. The column named *Link* shows the maximum value of the link capacity of the path, and the next columns have the have the path itself. For example in the line 1 is a path with 5 nodes and the link that has more capacity used has 72 OTUs and, the path is $3 \rightarrow 7 \rightarrow 9 \rightarrow 5 \rightarrow 3$.

The line 0 is used for support to this method, here we can find useful information. In the first position we have the number of entry's of the structure then, the next position saves the number of entry's that have a path with one node, then the number of entry's that have a path with two nodes... The Table 3.4 has 7 entry's that corresponds to the number of the first position of the line zero, than we have a zero, this means that we do not have a path with one node, in the next position appears the number 2 that means that we have two entry's with paths with two nodes.

#Line	*#nodes*	*Link capacity*	*Path*	*Path*	*Path*	*Path*	*Path*
0	**7**	**0**	**2**	**2**	**2**	**1**	**0**
1	5	72	3	7	9	5	3
2	4	70	2	5	8	6	
3	4	68	6	8	10	1	
4	3	80	7	4	3		
5	3	77	5	9	1		
6	2	55	1	2			
7	2	80	5	8			

Table 3.4: Structure for improvement of sort the decomposed arc, in the channel assignment process.

In the channel assignment task one of the steps is to decompose the OTUs path in the 3R regenerators nodes. Before this process, we compute the number of entry's that the structure use and the necessary space is reserved. Afterwards, the decomposition copies the new paths in to the new structure, updating the values in line 0. With the structure filled we can start to sort by the number of nodes of the path, *i.e*, longest path will be at the top of the structure. Starting from the last position of the line 0 towards the beginning, finding the first position different than zero. For example in the table we find the number 1 in the row number 5 [3]. At this point we know that we just have to found one entry with the number 5 in the column 0,the search starts from the first line until we finds the entry with 5 nodes. If the correspondent entry is in line 91 we just exchanged the lines $1 \rightarrow 91 \rightarrow 1$, and the search for path with five nodes is over. At this point we know were the list of path with five nodes starts

[3]The very first column of the Table 3.4, is just informative, and the next row is the row number zero.

and ends so, we take advantage and sort this path by the heaviest link capacity to the lower value. The next step is to verify if there are any path with 4 nodes, analysing the number in the forth position of the line 0. Here, there are two path, now, instead of starting in the beginning of the structure, we continue from the next position after the last entry with 5 nodes path and, once again we stop when we find the two path that have 4 nodes. When they are found and replaced the second sort will start, by just sorting the number of entry's equal to the number of the four node path. The process continues until we get to the path with 2 nodes here, we do not do the found and replace neither the sort in the link capacity. After the process for the paths with 3 nodes ends, the reaming path are with 2 nodes, and there are no point in sorting these path because they do not interfere with the channel assignment.

Finally, the example present in Table 3.4, shows one possible result of this process. We can see that the nodes are sorted from the longest to the shortest, ans the path with the same length are sorted from the path that have the biggest capacity link to the lowest, exception made to the path with 2 nodes that we do not sort in this process.

Chapter 4

Case Studies and Computational Results

This chapter presents the computational results obtained by the optimization algorithm described in the last chapter. This chapter includes the description of the case studies used in the computational results, the optimization results obtained on these case studies and the analysis of the obtained results.

4.1 Case Studies Description

The case studies were selected with the objective of testing and validating the implemented optimization algorithm and also of generating solutions for further analysis.

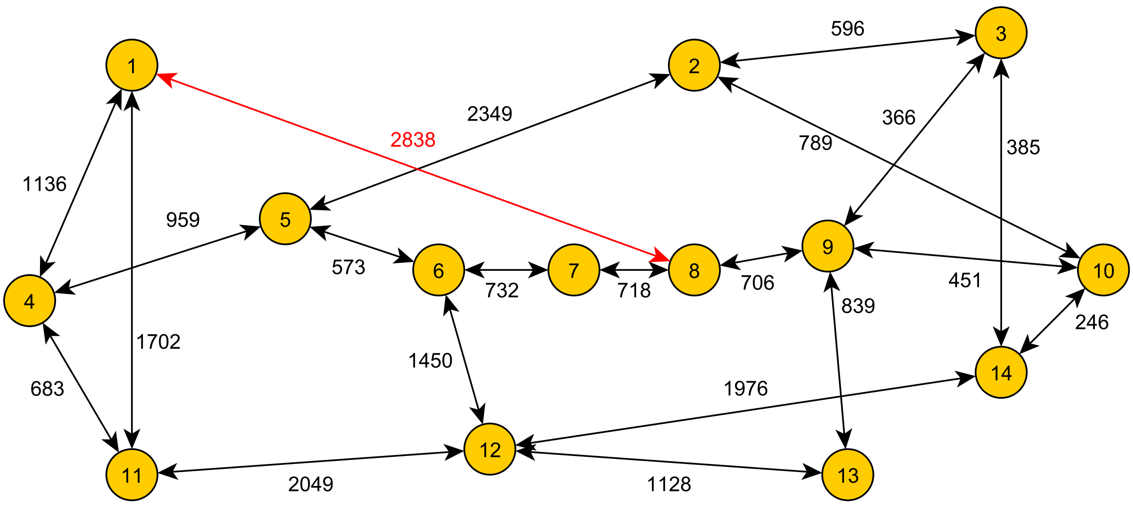

Figure 4.1: Illustration NSF Network.

First, the selected network topologies are described. Note that the four network topologies were selected to represent different topology characteristics in terms of link length, network size and node degree value.

Node	City	State	Country
1	Seattle	Washington	United States of America
2	Ann Arbor	Michigan	United States of America
3	Ithaca	New York	United States of America
4	Palo Alto	California	United States of America
5	Salt Lake City	Utah	United States of America
6	Boulder	Colorado	United States of America
7	Lincoln	Nebraska	United States of America
8	Champaign	Illinois	United States of America
9	Pittsburgh	Pennsylvania	United States of America
10	Princetom	New Jersey	United States of America
11	San Diego	California	United States of America
12	Houston	Texas	United States of America
13	Atalanta	Georgia	United States of America
14	College PK	Maryland	United States of America

Table 4.1: Correspondence between node number and their location at the NSF Network.

Node	City	Country	Node	City	Country
1	Lisbon	Portugal	11	Athenas	Greece
2	Dublin	Ireland	12	Zagreb	Croatia
3	Madrid	Spain	13	Vienna	Italy
4	London	England	14	Praha	Czech Republic
5	Paris	France	15	Berlin	Germany
6	Bruxelas	Belgium	16	Copenhagen	Denmark
7	Amsterdan	Netherlands	17	Oslo	Norway
8	Zurich	Switzerland	18	Stockolm	Sweden
9	Milan	Italy	19	Moscow	Russia
10	Roma	Italy			

Table 4.2: Correspondence between node number and their location at the EON Network.

Node	City	Country	Node	City	Country
1	Norden	Germany	10	Leipzig	Germany
2	Bremen	Germany	11	Frankfurt	Germany
3	Dortmund	Germany	12	Nurnberg	Germany
4	Hamburg	Germany	13	Manmheim	Germany
5	Essen	Germany	14	Munich	Germany
6	Hanmover	Germany	15	Karlsruhe	Germany
7	Dusseldorf	Germany	16	Ulm	Germany
8	Berlin	Germany	17	Stuttgart	Germany
9	Koln	Germany			

Table 4.3: Correspondence between node number and their location at the GBN Network.

Node	City	Country	Node	City	Country
1	Dublin	Ireland	17	Stockolm	Sweden
2	London	England	18	Helsinki	Finland
3	Paris	France	19	Tallim	Estonia
4	Bruxelas	Belgium	20	Riga	Latvia
5	Amsterdan	Netherlands	21	Vilnius	Lithuania
6	Luxembourg	Luxembourg	22	Warsav	Poland
7	Bern	Switzerland	23	Moscow	Russia
8	Ljubljana	Slovenija	24	Lisbon	Portugal
9	Zagreb	Croatia	25	Madrid	Spain
10	Budapeste	Hungary	26	Roma	Italy
11	Bratislava	Slovakia	27	Valletta	Republic of Malta
12	Wien	Austria	28	Athenas	Greece
13	Praha	Czech Republic	29	Sofia	Bulgaria
14	Berlin	Germany	30	Bucharest	Romania
15	Copenhagen	Denmark	31	Ankara	Turkey
16	Oslo	Norway	32	Nicosia	Cyprus

Table 4.4: Correspondence between node number and their location at the GEANT2 Network.

Networks	Nodes	Links	Average Nodal Degree	Average Link Length (km)
EON	19	37	3.89	753.8
GBN	17	26	3.06	143.1
GEANT2	32	52	3.25	677.0
NSFNET	14	21	3.00	991.7

Table 4.5: Main characteristics of all network topologies.

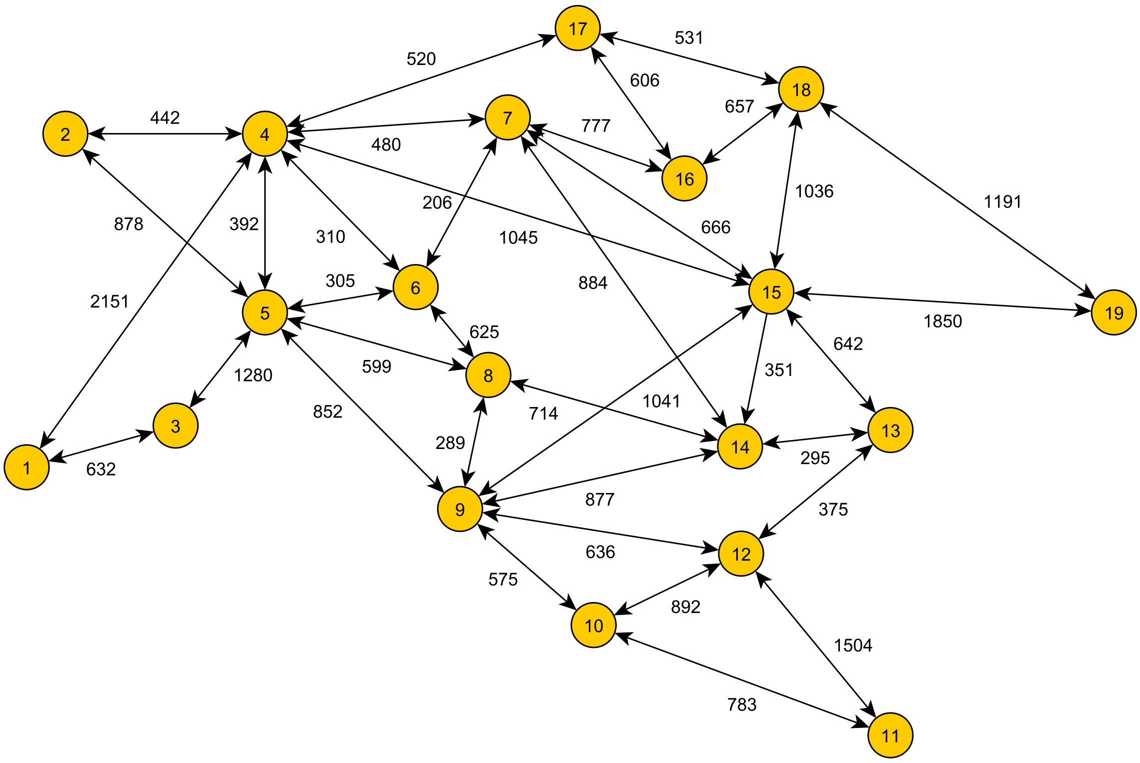

Figure 4.2: Illustration EON Network.

The following four network topologies were used:

- **National Science Foundation Network (NSFNET) -** This network topology (Figure 4.1) has 14 nodes and 21 bidirectional links. It is located in United States of America as can be seen by the node list in Table 4.1. This is an heterogeneous network since it includes both long links (the longest is $2838km$) and short links (the shorter is $246km$). It is the topology with the longest average link length. Note that this network includes one link which is longer than the maximum reach of any OTU type (the one highlighted in red in Figure 4.1) and therefore, this link was not considered (it could be used only if 3R regenerators were allowed in the middle of fibers).

- **European Optical Network (EON) -** This network topology (Figure 4.2) has 19 nodes and 37 bidirectional links. This network interconnect several European countries as the Table of nodes 4.2 shows. This topology is the one (among the four chosen ones) with the highest average node degree value and the second highest average link length.

- **German Backbone Network (GBN) -** This network topology (Figure 4.3) has 17 nodes and 26 bidirectional links. The GBN network topology is the smallest network (in terms of link average length) since it is a country network as can be seen in Table 4.3.

- **GEANT2 -** This network topology (Figure 4.4) has 32 nodes and 52 bidirectional links. GEANT2 network topology is the biggest network (in terms of number of nodes and

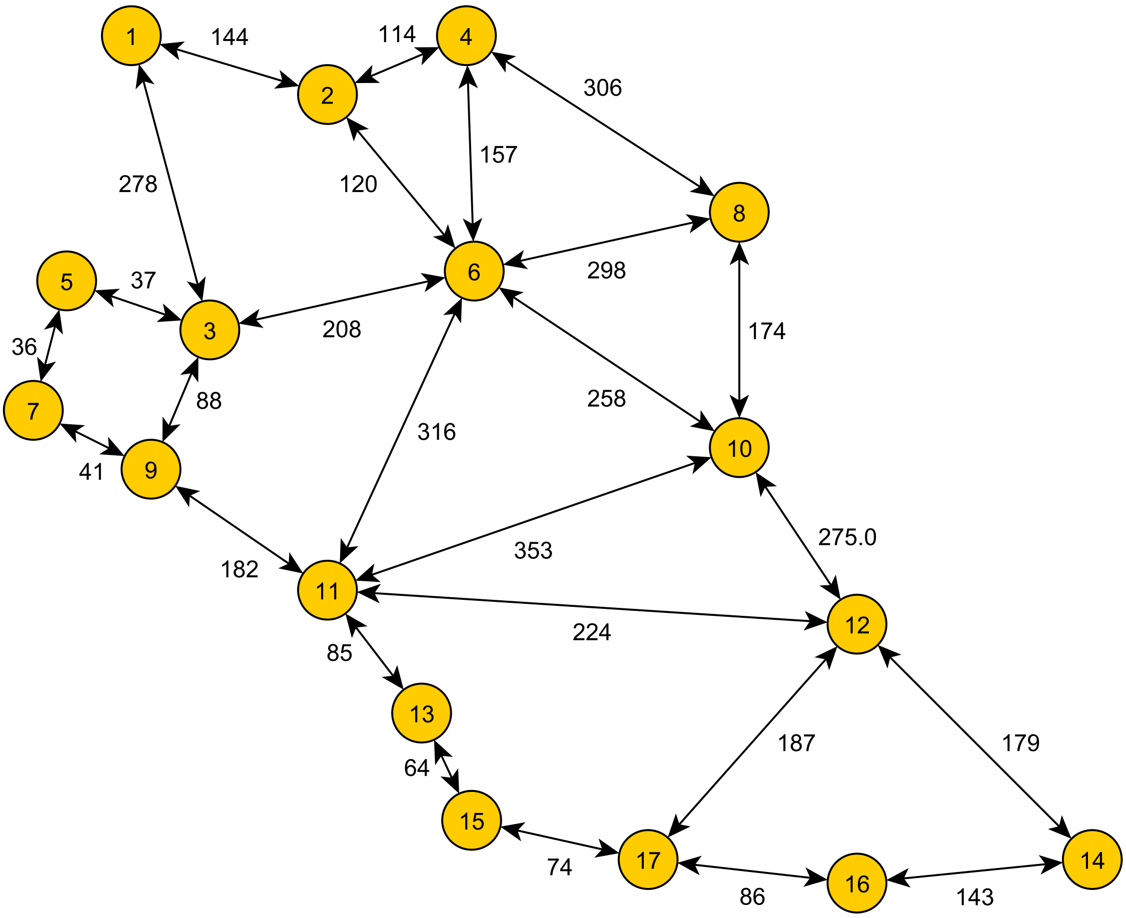

Figure 4.3: Illustration GBN Network.

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links) among the four selected ones. It is similar to the EON (in terms of location nodes and covered countries) but it includes more nodes and links as can be seen in Table 4.4.

The Table 4.5 resumes the main characteristics of all network topologies.

After the selection of the networks topologies, the aim was to generate a set of traffic scenarios to create different case studies. In order to accomplish that, and to cover different traffic scenarios with different traffic scaling factors, nine traffic matrices were randomly generated for each of the four network topologies. The nine traffic matrices (named T_1, T_2, ..., T_9), were generated in the following way:

1. **Origin - Destination node pair selection -** From the total Origin - Destination node pairs, we have randomly selected one third of them for T_1, T_2 and T_3, half of them for T_4, T_5 and T_6 and two thirds of them for T_7, T_8 and T_9 creating in this way traffic matrices with a growing number of Origin-Destination client demand pairs.

2. **Number and type of client demands -** For each Origin -Destination pair on each of the previous selected traffic matrices, we randomly generate the number and type of client demands with different percentages between them.

	EON					GBN				
T_i	E	B_{total}	P_{10G}	P_{40G}	P_{100G}	E	B_{total}	P_{10G}	P_{40G}	P_{100G}
T_1	57	18.8 T	53.2%	25.5%	21.3%	45	17.0 T	52.9%	23.5%	23.5%
T_2	57	19.6 T	25.5%	49.0%	25.5%	45	17.8 T	25.3%	49.4%	25.3%
T_3	57	21.5 T	16.3%	46.5%	37.2%	45	18.8 T	16.0%	46.8%	37.2%
T_4	85	23.5 T	53.2%	25.5%	21.3%	68	20.4 T	52.9%	23.5%	23.5%
T_5	85	24.6 T	25.5%	48.9%	25.7%	68	21.4 T	25.3%	49.4%	25.3%
T_6	85	26.9 T	16.3%	46.5%	37.2%	68	22.6 T	16.0%	46.8%	37.2%
T_7	114	29.5 T	53.1%	25.5%	21.4%	90	23.5 T	52.8%	23.4%	23.8%
T_8	114	30.7 T	25.5%	48.8%	25.7%	90	24.7 T	25.2%	49.3%	25.5%
T_9	114	33.7 T	16.3%	46.6%	37.1%	90	26.0 T	15.9%	46.8%	37.3%
	GEANT2					NSFNET				
T_i	E	B_{total}	P_{10G}	P_{40G}	P_{100G}	E	B_{total}	P_{10G}	P_{40G}	P_{100G}
T_1	165	18.5 T	54.1%	25.9%	20.0%	30	10.0 T	60.0%	20.0%	20.0%
T_2	165	18.7 T	26.7%	53.5%	19.8%	30	11.5 T	26.1%	52.2%	21.7%
T_3	165	20.7 T	19.3%	48.3%	32.4%	30	12.0 T	16.7%	50.0%	33.3%
T_4	248	21.3 T	53.9%	25.9%	20.2%	45	13.0 T	60.0%	20.0%	20.0%
T_5	248	21.6 T	26.7%	53.4%	19.9%	45	15.0 T	26.0%	52.0%	22.0%
T_6	248	23.9 T	19.2%	48.2%	32.6%	45	15.6 T	16.7%	50.0%	33.3%
T_7	330	24.5 T	54.0%	25.6%	20.4%	60	16.9 T	59.9%	20.1%	20.1%
T_8	330	24.9 T	26.6%	53.3%	20.1%	60	19.5 T	26.0%	52.0%	22.0%
T_9	330	27.6 T	19.2%	48.2%	32.6%	60	20.3 T	16.6%	50.0%	33.4%

Table 4.6: Traffic Matrices parameters, that result of the creation of cases studies for the four networks topologies.

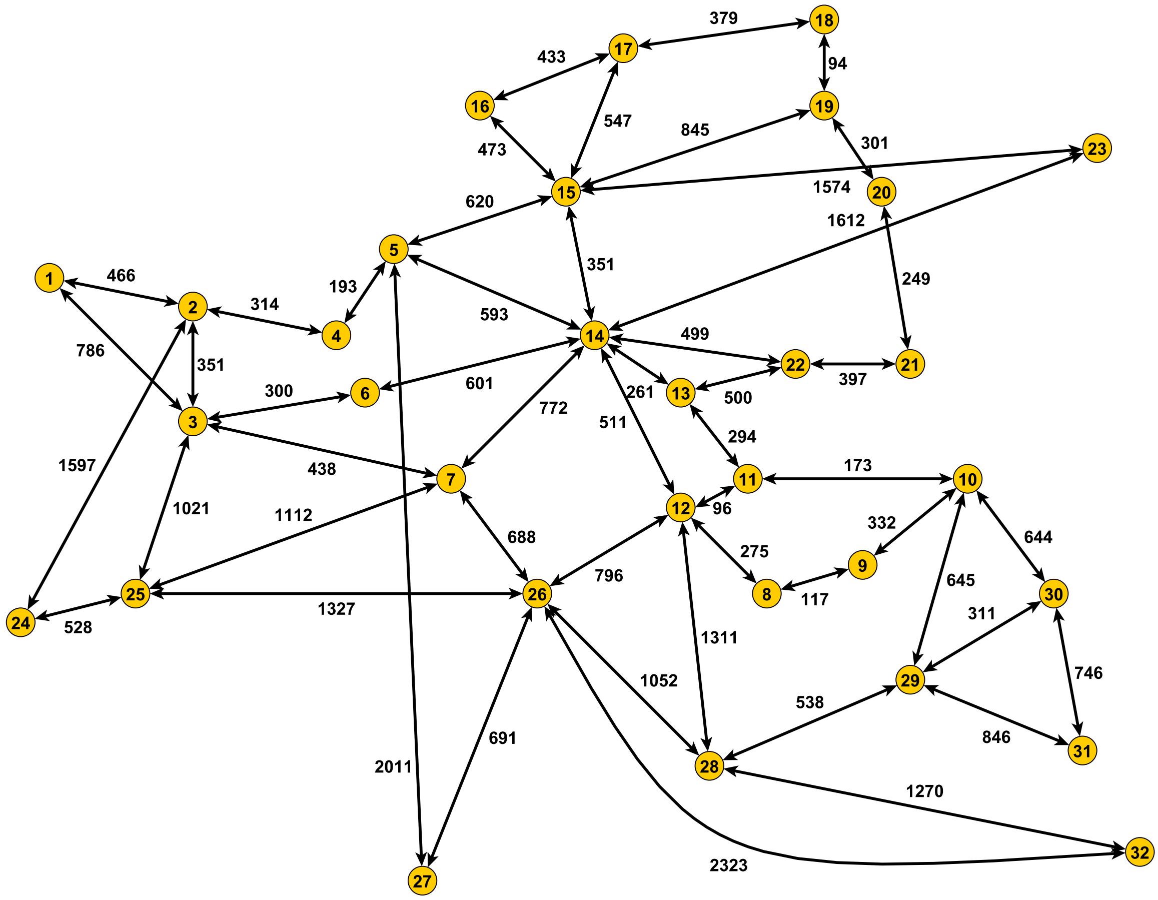


Figure 4.4: Illustration GEANT2 Network.

Table 4.6 shows the characteristics of all case studies, where E is the number of selected client demand Origin - Destination pairs , B_{total} is the total bandwidth of all client demands (in Terab/s) and P_{XG} (X = 10, 40 and 100) is the percentage of the total bandwidth of the client demands of type XG. As can be easily seen, from T_1 to T_9 on each network topology, the network matrices are of growing total demand and the demand percentages of the different client demand types are quite different. Note that the demand maximum values were chosen in order to get the more demanding scenarios in the limit of the network capacity.

In Appendix C, all traffic matrices are presented for all networks topologies. These values are defined (and are red by the tool) in the input file, as shown in Appendix A.

4.2 Analysis of Computational Efficiency

All computational results were obtained in a standard computational platform with two Intel Xeon processors (6 cores each) working at 2.30 GHz, 64GB of RAM and Windows 7 Enterprise operating system.

Before running the optimization algorithm to solve all case studies, a preliminary analysis was conducted to determinate the effectiveness on the number of threads to be launched. The idea is to determine the total number of cycles that are executed when different number of threads are launched. For that purpose, the T_1^{NSF} was used but, for this analysis, the tool was set for not sorting randomly the client demands in the Greedy part of the algorithm. In this way, the number of operations of each cycle is exactly the same for all cycles.

Threads	**1**	**12**	**24**	**36**	**48**	**60**	**64**
With SM		343453.00	413719.30	470108.90	494416.40	507939.00	498283.10
Without SM	3646.6	374424.90	450802.10	481615.80	505597.70	508080.50	493088.50
SP With SM		2043545.35	2461629.84	2797147.96	2941777.58	3022237.05	2964784.45
Virtual SP With SM		1471123.68	1772097.67	2013633.12	2117750.25	2175672.05	2134312.61
SP Without SM	216982.22	2227828.16	2682272.50	2865614.01	3008306.32	3023078.98	2933876.58
Virtual SP Without SM	156202.88	1603786.66	1930935.66	2062921.01	2165643.48	2176278.14	2112062.41

Table 4.7: Average number of cycles done in performance tests, and average number of Shortest Path used per second.(SP- Shortest path SM-Shared Memory)

We have executed ten runs with 60 seconds of time limit for 1, 12, 24, 36, 48, 60 and 64 threads. The results presented in Table 4.7, show the average number of cycles executed on each case. Both with and without shared memory options were considered for each case

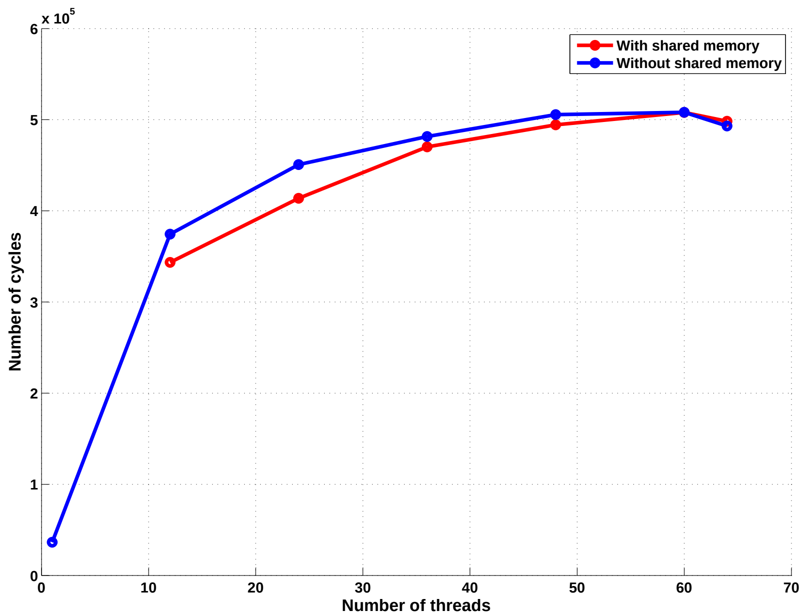
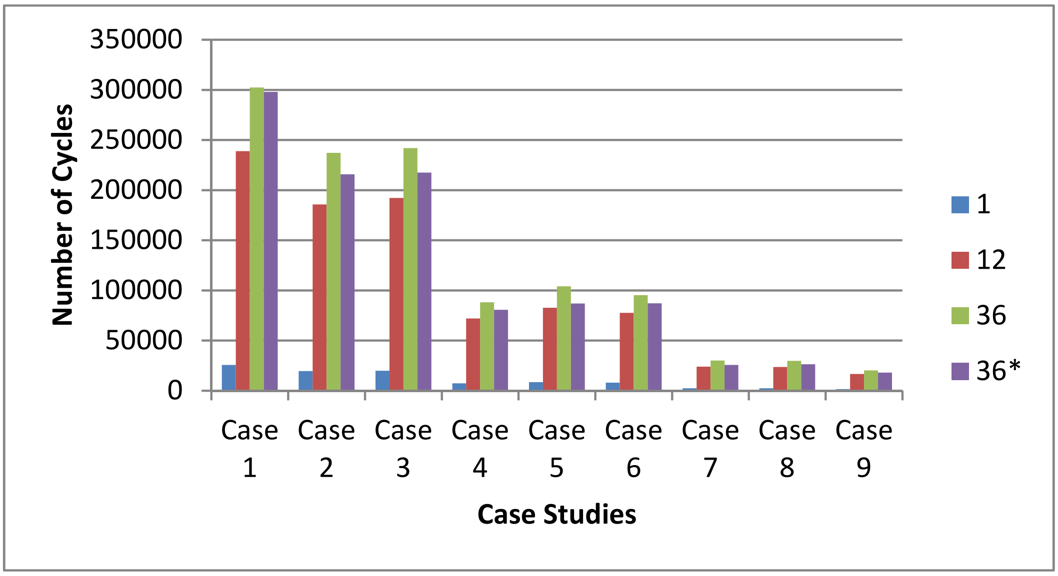
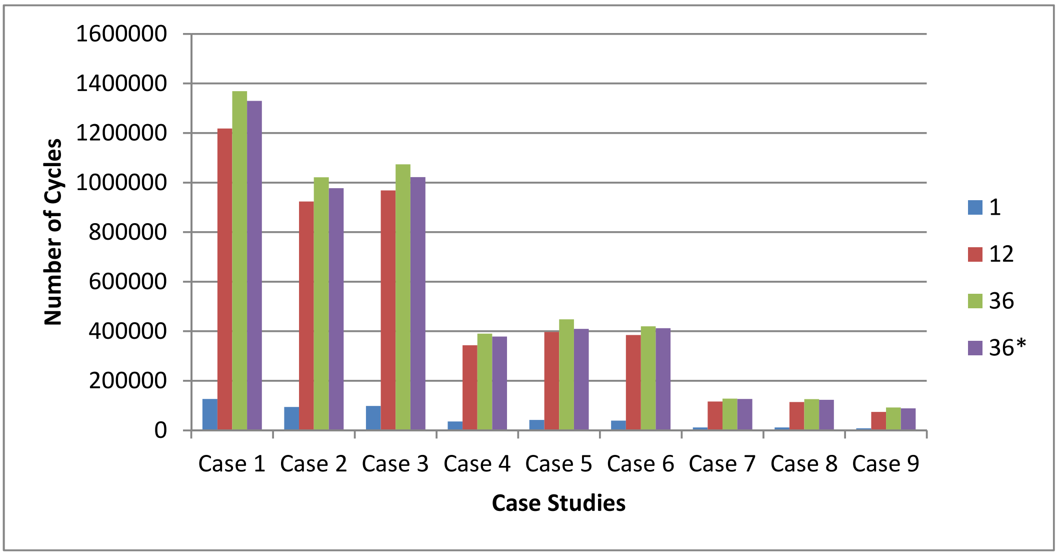


Figure 4.5: Graphic illustration of the average results acquired in the threads performance test (with and without shared memory).

except the case of 1 thread with shared memory since this case does not make sense. This table also shows the average number of executions of the shortest path (SP) functions per second.



a) 60 seconds



b) 300 seconds

Figure 4.6: Numbers cycles of all cases in the NSF Network. a) runtime of 60 seconds tests; b)runtime of 300 seconds;

Regarding the average number of SP executions per second, the values in Table 4.7 reflect the very high code efficiency that was obtained since even with 1 thread, the number of physical network SP executions was more than 240000 and the number of virtual layer SP executions was more than 170000. Note that the number of threads make these values much larger. For example, for the case of 12 threads with shared memory, the physical network SP function was executed more than 2000000 times in each second.

In Figure 4.5, the average number of cycles (in 60 seconds) are presented in blue for the runs without shared memory and in red for the runs with shared memory. The first conclusion from this figure is that the number of cycles for the runs with shared memory is always lower than the runs without shared memory. This is an expected result since the shared memory option uses semaphores (to access it) that penalizes slightly the total number of cycles. This figure shows a significant difference between the number of cycles from 1 to the 12 threads, an expected result since the total number of cores of the computational platform is 12. From 12 to 36 threads, we observe a continuous growth in the obtained number of cycles, although with a less pronounced growth. Then, it starts to stagnate from 36 to 60 and even decrease in the end with the 64 threads. From this figure, we have decided to run our tests with 1, 12 and 36 without shared memory and 36$*$ with shared memory.

After this decision, all case studies of all network topologies were solved by the optimization algorithm presented in the previous chapter. We have run each case 10 times for a runtime limit of 60 seconds and 10 times for a runtime limit of 300 seconds. The solutions obtained in all runs and all case studies of all networks topologies are presented in the Appendix D. In addition, Appendix E presents the average, best and worse solution (among the 10 available solutions) found in all cases.

In Figure 4.6, two graphs are presented with the average number of cycles (for the different number of threads) for all case studies of NSF network topology. Sub-graph a) is for the 60 second runs and sub-graph b) is for the 300 second runs. The first conclusion is that a) and b) are similar and, as expected, as the cases become more difficult (in terms of number of client demands and size of the topology) the number of cycles reduces. Comparing the number of cycles case by case, we see the similarity with Figure 4.5. Here, we observe that there is a big difference from 1 thread to 12 threads, then between 12 and 36 there is an increase that is more evident in sub-graph a), and between 36 threads with and without shared memory there exists a small decrease in the number of cycles. Comparing sub-graphs a) and b), it is clear that in the 60 second cases, the differences are more visually evident. On average, the gain (in number of cycles) from 1 to 12 threads is 9.76, from 1 to 36 is 12.18 and from 1 to 36$*$ is 10.94, in the case of 60 seconds of runtime. For 300 second cases, the gain from 1 to 12 thread is 9.64, from 1 to 36 is 10.85 and from 1 to 36$*$ is 10.45. The gain from 1 to 12 is very similar in both cases; from 12 to 36 there as a small difference; finally in the cases of 36$*$ threads it is also similar.

Table 4.8 presents the average gain (in number of cycles) of using multiple threads when compared with using a single thread. One particularity is that the gains are more similar among the network topologies with less number of nodes (NSF and GBN). This fact is relevant in two aspects. First, the time spent by the shortest path functions is determinant for the overall performance. Second, the biggest network topologies (that have also more number of client demands) make the Local Search to do more cycles, on average, decreasing in this way the overall number of cycles. The final conclusion from Table 4.8 is that using threads, we obtain a gain of around 10 with 12 threads and a little bit more with 36 threads.

Another relevant parameter that has an important role on computational efficiency is

Network	Gain 12 Threads	Gain 36 Threads	Gain 36* Threads
NSF 60	9.76	12.18	10.94
NSF 300	9.64	10.85	10.45
GBN 60	9.49	11.70	10.72
GBN 300	9.49	12.00	10.21
EON 60	10.16	12.49	10.74
EON 300	10.15	11.02	10.53
GEANT2 60	10.48	12.53	10.77
GEANT2 300	10.91	11.42	10.98
average	10.01	11.77	10.67

Table 4.8: Average number of cycles for all network topologies and all thread configurations (for 60 and 300 seconds).

the algorithm ability to handle unfeasible solutions and turn them feasible. For case studies with more demanding traffic matrices, the Greedy algorithm hardly finds a feasible solution. Therefore, we let it to find an unfesible solution and, then, we hope that the Local Search algorithm can make it feasible. Otherwise, *i.e.*, if we didn't let the Greedy algorithm to create unfeasible solutions, this would lead to a tremendous use of the Greedy algorithm without any creation of valid solutions to deliver to the Local Search algorithm. For example, in T_9^{NSF} all the Greedy solutions were unfeasible and, so, if the Local Search had not a way to deal with unfeasible solutions, it was not possible to find any valid solution. In this case the Local Search turn approximately 55% of the solutions feasible, and so, this is another way of enhancing the algorithm computational efficiency.

4.3 Solution Analysis

The number of case studies and number of network topologies considered have created a considerable amount of data results to analyse. The performance evaluation was made in the previous section 4.2. Table 4.10 (see also the Header symbol Table 4.9 for the meaning of the headers of Table 4.10) shows all best solutions found in the runs made with a runtime limit of 300 seconds, for all network topologies and all case studies.

Symbol	Name
$\#T$	Number of Threads
t_E	Time of Execution
C	Best Cost Solution found
CA	Highest Channel Assigned
t_{sol}	Found Solution Time
$\#i$	Number of Iterations
$\#IS$	Number of Invalid Solutions
$\#G_U$	Number of Greedy Solutions Unfeasible
$\#LS_U$	Number of Local Search Solutions Unfeasible
UD	Unfeasible Degree
$\#IM$	Number of Invert Multiplex used
C_{IM}	Cost % of Invert Multiplex
$\#MX$	Number of Muxponders placed
C_{MX}	Cost % of Muxponders
$\#TX$	Number of Transponders placed
C_{TX}	Cost % of Transponders
$\#3R$	Number of $3R$ regenerators placed
C_{3R}	Cost % of $3R$ regenerators
$\#10$	Number of Multi-Hop Grooming of $10Gb/s$
$\%10$	Traffic % of Multi-Hop Grooming of $10Gb/s$
$\#40$	Number of Multi-hop Grooming of $40Gb/s$
$\%40$	Traffic % of Multi-hop Grooming of $40Gb/s$
$\bar{m}F$	Average Fragmentation at Channel Assigned
MF	Max Fragmentation at Channel Assigned
C_{IM}	Cost of Invert Multiplexers
C_{MX}	Cost of Multiplexers
C_{TX}	Cost of Transponders
C_{3R}	Cost of $3R$ regenerators

Table 4.9: Header symbols and their description.

	COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
Networks	$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
NSF																												
Case 1	36*	313.73	4438.80	58.00	282.36	1338887.00	0.00	0.00	0.00	0.00	14.00	6.31	308.00	35.05	126.00	22.30	159.0	36.33	12.00	2.00	0.00	0.00	4.15	25.00	2800.00	15560.00	9900.00	16128.00
Case 2	36	313.75	4882.80	62.00	4.87	1015031.00	0.00	0.00	0.00	0.00	16.00	6.54	152.00	16.52	334.00	47.22	140.0	29.53	12.00	4.00	0.00	0.00	5.75	30.00	3200.00	8080.00	23100.00	14448.00
Case 3	36*	313.52	5526.00	80.00	48.30	1062128.00	0.00	1062128.00	0.00	0.00	24.00	8.69	102.00	10.10	356.00	47.77	170.0	33.44	6.00	3.00	0.00	0.00	5.75	35.00	4800.00	5580.00	26400.00	18480.00
Case 4	12	300.25	5373.60	59.00	168.89	338127.00	0.00	0.00	0.00	0.00	20.00	7.41	400.00	37.91	162.00	23.33	160.0	30.84	24.00	3.08	0.00	0.00	4.10	35.00	4000.00	20480.00	12600.00	16656.00
Case 5	12	300.78	6748.80	80.00	239.26	384789.00	0.00	171506.00	6785.00	0.00	18.00	5.30	196.00	15.38	438.00	45.08	217.0	33.66	11.00	2.82	0.00	0.00	8.20	44.00	3600.00	10440.00	30600.00	22848.00
Case 6	12	300.33	7328.80	78.00	285.15	388491.00	0.00	79793.00	0.00	0.00	28.00	7.62	140.00	9.75	466.00	47.38	238.0	35.03	15.00	5.77	0.00	0.00	6.25	38.00	5600.00	7160.00	34800.00	25728.00
Case 7	12	300.27	7770.00	80.00	226.20	115977.00	0.00	115977.00	21162.00	0.00	16.00	4.10	506.00	34.88	222.00	23.07	254.0	37.52	36.00	3.55	0.00	0.00	4.15	41.00	3200.00	27220.00	18000.00	29280.00
Case 8	36*	301.20	8338.00	80.00	150.88	122793.00	0.00	122793.00	5604.00	0.00	20.00	4.80	236.00	16.84	574.00	48.43	236.0	29.94	30.00	5.92	0.00	0.00	4.80	26.00	4000.00	14040.00	40380.00	24960.00
Case 9	36*	300.44	9470.40	80.00	285.73	88213.20	0.00	88213.00	39695.00	0.00	26.00	5.49	188.00	15.14	568.00	45.87	286.0	39.94	29.00	8.58	0.00	0.00	4.75	40.00	5200.00	14340.00	43440.00	37824.00
GBN																												
Case 1	36	313.73	4726.00	56.00	145.33	504218.00	0.00	0.00	0.00	0.00	0.00	0.00	462.00	49.11	280.00	50.68	0.0	0.00	12.00	1.33	0.00	0.00	12.19	30.00	0.00	23260.00	24000.00	0.00
Case 2	12	300.38	5174.00	73.00	264.42	504188.00	0.00	17702.00	1285.00	0.00	0.00	0.00	208.00	22.87	530.00	77.06	0.0	0.00	8.00	1.78	0.00	0.00	16.92	40.00	0.00	11840.00	39900.00	0.00
Case 3	36	306.02	5566.00	55.00	178.12	493897.00	0.00	0.00	0.00	0.00	0.00	0.00	146.00	14.83	580.00	85.10	0.0	0.00	11.00	3.67	0.00	0.00	10.69	23.00	0.00	8260.00	47400.00	0.00
Case 4	12	300.44	5680.00	77.00	89.33	199888.00	0.00	89432.00	12639.00	0.00	0.00	0.00	544.00	49.21	336.00	50.62	0.0	0.00	17.00	1.57	0.00	0.00	13.54	31.00	0.00	28000.00	28800.00	0.00
Case 5	12	300.27	6224.00	78.00	84.91	175880.00	0.00	151009.00	10387.00	0.00	0.00	0.00	252.00	23.04	636.00	76.80	0.0	0.00	14.00	2.59	0.00	0.00	12.38	36.00	0.00	14360.00	47880.00	0.00
Case 6	12	300.39	6692.00	73.00	32.28	225541.00	0.00	1827.00	0.00	0.00	0.00	0.00	188.00	14.97	696.00	84.79	0.0	0.00	21.00	5.83	0.00	0.00	12.35	31.00	0.00	10040.00	56880.00	0.00
Case 7	12	300.58	6596.00	80.00	142.46	106344.00	0.00	106344.00	70422.00	0.00	0.00	0.00	572.00	49.42	388.00	50.58	0.0	0.00	27.00	2.17	0.00	0.00	9.38	26.00	0.00	32600.00	33360.00	0.00
Case 8	36	316.01	7228.00	80.00	2.17	70851.00	0.00	70850.00	16456.00	0.00	0.00	0.00	290.00	23.21	734.00	76.07	0.0	0.00	27.00	4.35	0.00	0.00	6.73	24.00	0.00	16900.00	55380.00	0.00
Case 9	36	315.20	7920.00	80.00	295.90	40566.00	0.00	40566.00	12.00	0.00	0.00	0.00	242.00	22.37	732.00	77.05	0.0	0.00	32.00	7.73	0.00	0.00	9.46	29.00	0.00	17820.00	61380.00	0.00
EON																												
Case 1	12	300.27	6912.80	59.00	14.31	122937.00	0.00	0.00	0.00	0.00	20.00	5.74	512.00	38.11	300.00	33.58	134.0	21.76	19.00	1.90	0.00	0.00	6.05	31.00	4000.00	26560.00	23400.00	15168.00
Case 2	36*	301.19	7980.80	67.00	261.18	128735.00	0.00	1.00	0.00	0.00	22.00	5.51	246.00	17.22	558.00	50.75	192.0	26.52	17.00	3.40	0.00	0.00	5.81	25.00	4400.00	13740.00	40500.00	21168.00
Case 3	1	300.44	7970.80	51.00	204.25	16675.00	0.00	0.00	0.00	0.00	22.00	5.52	184.00	12.75	638.00	63.61	116.0	18.13	13.00	3.71	0.00	0.00	4.78	37.00	4400.00	10160.00	50700.00	14448.00
Case 4	36	307.12	8557.20	62.00	113.44	65340.00	0.00	159.00	0.00	0.00	20.00	4.67	634.00	38.73	380.00	35.06	165.0	21.54	30.00	2.40	0.00	0.00	8.03	34.00	4000.00	33140.00	30000.00	18432.00
Case 5	36*	301.35	9708.80	79.00	93.10	49246.00	0.00	49246.00	2074.00	0.00	22.00	4.53	338.00	21.88	662.00	50.55	185.0	23.04	34.00	5.44	0.00	0.00	9.97	41.00	4400.00	21240.00	49080.00	22368.00
Case 6	12	300.63	10486.80	78.00	277.51	54835.00	0.00	54835.00	9.00	0.00	46.00	8.72	248.00	13.34	764.00	56.56	189.0	20.74	32.00	7.31	0.00	0.00	10.00	43.00	9200.00	14080.00	59700.00	21888.00
Case 7	36	313.74	11753.20	80.00	52.52	20508.00	0.00	20508.00	5559.00	0.00	24.00	4.03	758.00	36.88	458.00	30.76	258.0	26.94	54.00	3.45	0.00	0.00	5.76	41.00	4800.00	43960.00	36660.00	32112.00
Case 8	36	315.54	12095.20	78.00	213.13	31279.00	0.00	18166.00	0.00	0.00	40.00	6.57	382.00	18.55	862.00	51.22	259.0	23.03	41.00	5.24	0.00	0.00	10.97	54.00	8000.00	22580.00	62340.00	28032.00
Case 9	36*	301.52	14422.00	80.00	209.90	16778.00	0.00	16778.00	337.00	0.00	44.00	6.10	318.00	12.56	970.00	53.21	340.0	28.12	50.00	9.12	0.00	0.00	7.65	34.00	8800.00	18120.00	76740.00	40560.00
GEANT2																												
Case 1	36*	301.72	7588.00	63.00	43.13	7984.00	0.00	0.00	0.00	0.00	14.00	3.69	536.00	38.27	300.00	30.84	188.0	27.20	59.00	5.90	0.00	0.00	13.46	46.00	2800.00	29040.00	23400.00	20640.00
Case 2	36*	301.56	7920.40	80.00	268.98	8489.00	0.00	6462.00	0.00	0.00	10.00	2.53	324.00	20.93	560.00	49.69	199.0	26.85	58.00	11.60	0.00	0.00	18.52	62.00	2000.00	16580.00	39360.00	21264.00
Case 3	36	313.37	8769.20	80.00	289.30	8837.00	0.00	8664.00	0.00	0.00	36.00	8.09	272.00	15.45	598.00	50.20	201.0	24.75	53.00	13.25	0.00	0.00	17.38	62.00	7200.00	13760.00	44700.00	22032.00
Case 4	36	313.12	9494.00	80.00	109.84	2449.00	0.00	2449.00	0.00	0.00	20.00	4.12	672.00	36.24	342.00	27.24	266.0	30.15	115.00	10.00	0.00	0.00	17.33	57.00	4000.00	35200.00	26460.00	29280.00
Case 5	36	310.21	9220.80	79.00	23.59	3713.00	0.00	3700.00	0.00	0.00	22.00	4.69	392.00	20.91	640.00	47.12	219.0	25.66	88.00	15.30	0.00	0.00	16.52	58.00	4400.00	19600.00	44160.00	24048.00
Case 6	12	301.94	10142.40	78.00	262.30	3365.00	0.00	3359.00	0.00	0.00	36.00	7.10	336.00	16.56	696.00	51.82	220.0	24.51	89.00	19.35	0.00	0.00	19.71	65.00	7200.00	16800.00	52560.00	24864.00
Case 7	12	303.64	10447.60	79.00	211.41	1580.00	0.00	1578.00	0.00	0.00	18.00	3.40	776.00	38.57	388.00	28.96	273.0	27.74	107.00	8.09	0.00	0.00	15.79	56.00	3600.00	40840.00	30660.00	29376.00
Case 8	12	303.67	10844.80	79.00	222.83	1357.00	0.00	1357.00	0.00	0.00	36.00	6.55	464.00	21.10	728.00	44.96	274.0	26.01	119.00	17.98	0.00	0.00	17.08	56.00	7200.00	23200.00	49440.00	28608.00
Case 9	36	316.29	12459.60	80.00	58.52	1628.00	0.00	1628.00	2.00	0.00	48.00	7.70	398.00	16.81	780.00	47.10	316.0	28.39	113.00	21.36	0.00	0.00	15.02	57.00	9600.00	20940.00	58680.00	35376.00

Table 4.10: Best result for every network topology and all cases studies for running time of 300 seconds.

4.3.1 Cost Analysis

Through cost analysis, several details about the optimization algorithm of the tool can be obtained on the performance versus the two memory approaches and performance versus number of threads.

Time	60 seconds				300 seconds			
Network	Threads	Sol. Cost	Highest Channel	Sol. Time	Threads	Sol. Cost	Highest Channel	Sol. Time
NSF								
Case 1	36	4438.80	59.00	14.71	36*	4438.80	58.00	282.36
Case 2	12	4882.80	62.00	6.07	36	4882.80	62.00	4.87
Case 3	36	5526.00	80.00	9.44	36*	5526.00	80.00	48.30
Case 4	36	5377.20	59.00	15.68	12	5373.60	59.00	168.89
Case 5	12	6754.80	80.00	47.55	12	6748.80	80.00	239.26
Case 6	12	7331.20	78.00	38.31	12	7328.80	78.00	285.15
Case 7	36	7791.20	80.00	44.15	12	7770.00	80.00	226.20
Case 8	36*	8352.40	80.00	58.87	36*	8338.00	80.00	150.88
Case 9	36*	9996.00	80.00	50.36	36*	9470.40	80.00	285.73
GBN								
Case 1	36*	4730.00	57.00	3.29	36	4726.00	56.00	145.33
Case 2	36	5176.00	75.00	19.11	12	5174.00	73.00	264.42
Case 3	12	5566.00	56.00	46.91	36	5566.00	55.00	178.12
Case 4	36*	5684.00	77.00	21.84	12	5680.00	77.00	89.33
Case 5	12	6226.00	79.00	22.60	12	6224.00	78.00	84.91
Case 6	36	6700.00	73.00	57.95	12	6692.00	73.00	32.28
Case 7	12	6604.00	80.00	47.46	12	6596.00	80.00	142.46
Case 8	36	7228.00	80.00	3.85	36	7228.00	80.00	2.17
Case 9	36*	7924.00	80.00	32.31	36	7920.00	80.00	295.90
EON								
Case 1	12	6914.40	61.00	44.48	12	6912.80	59.00	14.31
Case 2	36*	7970.80	53.00	28.44	36*	7980.80	67.00	261.18
Case 3	36*	7995.20	51.00	59.11	1	7970.80	51.00	204.25
Case 4	12	8624.80	65.00	36.13	36	8557.20	62.00	113.44
Case 5	36*	9718.40	80.00	28.38	36*	9708.80	79.00	93.10
Case 6	36	10493.20	78.00	8.21	12	10486.80	78.00	277.51
Case 7	36*	11753.20	80.00	52.93	36	11753.20	80.00	52.52
Case 8	12	12094.40	78.00	43.37	36	12095.20	78.00	213.13
Case 9	12	14466.40	80.00	18.85	36*	14422.00	80.00	209.90
GEANT2								
Case 1	12	7588.00	63.00	6.79	36*	7588.00	63.00	43.13
Case 2	36	7912.80	80.00	17.94	36*	7920.40	80.00	268.98
Case 3	12	8777.20	79.00	23.84	36	8769.20	80.00	289.30
Case 4	36*	9523.20	80.00	3.74	36	9494.00	80.00	109.84
Case 5	12	9240.80	78.00	48.70	36	9220.80	79.00	23.59
Case 6	36*	10156.80	80.00	36.32	12	10142.40	78.00	262.30
Case 7	36*	10471.20	80.00	36.66	12	10447.60	79.00	211.41
Case 8	12	10905.60	80.00	49.06	12	10844.80	79.00	222.83
Case 9	12	12459.60	80.00	26.83	36	12459.60	80.00	58.52

Table 4.11: Best solutions found in all Networks topologies and in every Case Studies.

Table 4.11 shows the best solutions obtained for each case study and for each maximum runtime (60 and 300 seconds). For each best solution, it is indicated the used number of threads, the solution cost, the highest assigned WDM channel and the time instant when the solution was found. Note that for many case studies, the same best solution was found in different algorithm parameters. The parameters shown in the table are the ones that found the best solution in the smallest runtime.

As shown in Table 4.11 in all cases (even in the less demanding ones), the maximum runtime is a factor of relevance. For example, in T_1^{NSF} case, the overall best solution has the same cost in both 60 and 300 seconds run, but in the last case it has found a solution that uses one less channel. Some cases, like T_2^{NSF}, have found the same solution in both 60 and 300 seconds runs. In such cases, the tool does not need the longer runtime limit to find this best solution.

As expected, in the majority of the cases, the best solutions are found with the runtime limit of 300 seconds and when we use multiple threads. Note that the proposed algorithm is stochastic and, therefore, it might happen the opposite. One example is the T_3^{EON} where the best solution was found (in a shorter runtime) in the runs with a single thread.

Time	60 seconds					300 seconds				
Network		S. Cost	H. Channel	S. Time	Cycles		S. Cost	H. Channel	S. Time	Cycles
GBN										
Case 1	1	4736.00	58.00	27.49	9408.60	1	4731.20	59.40	160.99	46871.40
Case 1	12	4731.40	58.10	38.55	91970.30	12	4730.00	57.20	111.36	457708.80
Case 1	36	4730.00	59.00	27.99	112217.20	36	4729.20	56.80	130.37	509576.30
Case 1	36*	4730.00	59.00	27.99	112217.20	36*	4730.00	56.80	134.19	492309.00
Case 5	1	6234.80	78.80	24.82	3431.50	1	6231.60	78.30	96.32	17176.80
Case 5	12	6229.40	78.90	25.84	32916.70	12	6227.20	78.60	118.80	165906.90
Case 5	36	6229.80	78.60	33.48	42096.10	36	6228.00	79.00	124.00	184143.50
Case 5	36*	6230.00	78.80	25.18	35210.80	36*	6227.20	79.00	139.67	174008.30
Case 9	1	7970.20	80.00	28.90	740.40	1	7947.00	80.00	149.28	3693.90
Case 9	12	7944.80	80.00	31.34	7614.10	12	7934.00	80.00	180.56	37701.00
Case 9	36	7943.96	80.00	32.88	9230.60	36	7929.96	80.00	207.78	93482.70
Case 9	36*	7942.40	80.00	43.02	8086.70	36*	7934.00	80.00	93.47	38475.00
GEANT2										
Case 2	1	8022.04	78.70	33.88	163.20	1	7986.44	78.30	117.63	800.30
Case 2	12	7964.68	78.40	29.72	1764.50	12	7946.96	78.90	123.95	8548.10
Case 2	36	7960.32	78.60	30.26	2109.10	36	7943.84	78.40	141.13	9056.60
Case 2	36*	7971.40	78.90	34.06	1771.10	36*	7944.52	79.20	163.24	8602.40
Case 6	1	10264.96	79.60	27.80	66.40	1	10240.76	79.90	97.08	321.00
Case 6	12	10231.80	79.80	23.44	699.70	12	10180.40	79.30	132.31	3344.40
Case 6	36	10212.80	79.70	30.07	817.40	36	10181.60	79.60	122.15	3515.80
Case 6	36*	10210.60	79.90	17.75	717.10	36*	10188.84	79.80	142.36	3408.40
Case 7	1	10639.20	80.00	25.76	31.50	1	10578.68	79.90	168.93	152.30
Case 7	12	10567.72	80.00	30.42	324.50	12	10512.72	79.80	104.00	1576.00
Case 7	36	10562.32	79.80	38.48	386.30	36	10517.88	80.00	171.98	1629.90
Case 7	36*	10547.04	80.00	38.27	341.50	36*	10509.68	79.70	168.30	1570.20

Table 4.12: Average values of solution parameters (cost value, maximum assigned WDM channel and number of cycles) found in GBN and GEANT2 Network topologies in some case studies.

For the analysis of the different number of threads and memory method used, Table 4.12 presents the average values of solution parameters (cost value and maximum assigned WDM channel) and number of cycles for all considered thread configurations in only a selected set of network topologies (GBN and GEANT2) and case studies (1, 5 and 9 for GBN and 2, 6 and 7 for GEANT2). The results of this table show clearly that, on average, the worse solutions are the ones obtained in the cases with a single thread and that the multiple thread cases (12, 36 and 36$*$) have similar results. These results validate the option of this work in developing a multi-thread version of the optimization algorithm.

Following previous conclusions, we observe in this table that the average gain in number of cycles from the 60 second runs to the 300 second runs varies between case studies but is around 5 on average.

Another observation from the analysis of Table 4.12 is that there is a huge difference in the number of cycles between the two network topologies. In T_7^{GEANT2} with 36 threads, 300 seconds have run 1629.09 cycles, whereas in T_9^{GBN} case, 300 seconds have run 93482.70 cycles. This reflects the fact that the $GEANT2$ is a much bigger network topology (with much more number of client demands) than GBN.

Analysing the number of cycles for the four thread configurations of the same case study, it is clear that configurations 12 and 36$*$ are relatively close. Remember that the shared memory method uses semaphores. Therefore, if this method were used with only 12 threads, it might have been a valid option to find good solutions since there were less 24 threads competing for the access to the shared memory. Unfortunately, the due to lack of time, this configuration was not tested.

The graph presented in Figure 4.7 shows the distribution of the OTN optical element costs of the best solutions found within 300 seconds.

Let us consider first the GBN case. In this case, there is no use of 3R regenerators and

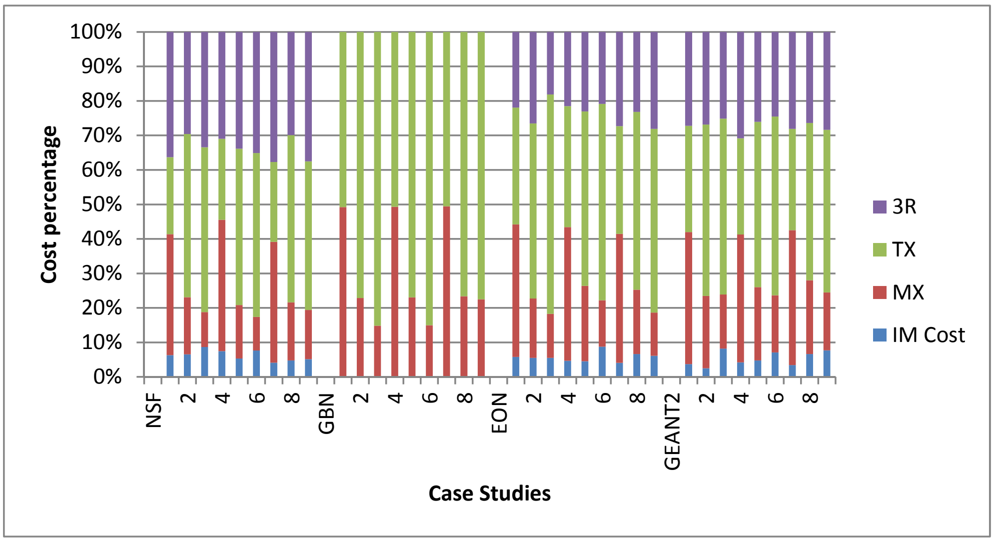


Figure 4.7: Graph illustrating the cost distribution of the OTN optical elements.

neither of inverse muxponders. This fact is associated with the Average Link Length of the *GBN* network (revisit Table 4.5) which is quite small (143.1) and so with the OTUs reach length around $2000km$, there is no need of using 3R regenerators (and if they were used, the cost would be penalized). The absence of inverse muxponders is also understandable since this operation is normally used to reduce the cost of the 3R regenerators (by extending the maximum reach of OTUs). Since in this case there are no 3R regenerators, inverse multiplexing is also not worthwhile.

Considering now the other network topologies (NSF, EON and $GEANT2$), the inverse multiplexing costs used in their best solutions, although relative low (in no case it exceeds the 10% of the total costs), are used by the algorithm to obtain lower cost solutions. The 3R regenerators are used in an almost constant percentage of the overall cost among all these cases. This is also related with some parameters of the network topologies that include Origin-Detination pairs whose shortest path distance is above the reach of any OTU type. The GEANT2 network topology is the case that has more nodes and it is also the case that presents the most constant 3R regenerators percentage costs among all nine case studies.

The transponders and muxponders are responsible for the higher percentage of the cost. Every network topology shows a similar behaviour regarding these costs. Let us take the GBN network topology as example. It is shown that the cases 1, 4 and 7 are the ones with the higher costs of the muxponders (around 50%). Then ,in cases 2, 5 and 8 the muxponders cost reduces to near 30%, and the remaining cases reduces to around 20%. This behaviour is easily explained by consulting Table 4.6. There is a relation with these costs results and the data of Table 4.6: the case studies that have an higher percentage of lower client demand types use more muxponders that groom such client demands.

4.3.2 Unfeasible cycles

This section will show the numbers of greedy unfeasible solutions, and the local search ability to turn them feasible.

Networks	Thread	Cycles	Greedy	LS	%Unf greedy	% Ls solved
NSF						
Case 1	36*	1338887	0	0	0.00%	0.00%
Case 2	36	1015031	0	0	0.00%	0.00%
Case 3	36*	1062128	1062128	0	100.00%	100.00%
Case 4	12	338127	0	0	0.00%	0.00%
Case 5	12	384789	171506	6785	44.57%	96.04%
Case 6	12	388491	79793	0	20.54%	100.00%
Case 7	12	115977	115977	21162	100.00%	81.75%
Case 8	36*	122793	122793	5604	100.00%	95.44%
Case 9	36*	88213	88213	39695	100.00%	55.00%
GBN						
Case 1	36	504218	0	0	0.00%	0.00%
Case 2	12	504188	17702	1285	3.51%	92.74%
Case 3	36	493897	0	0	0.00%	0.00%
Case 4	12	199888	89432	12639	44.74%	85.87%
Case 5	12	175880	151009	10387	85.86%	93.12%
Case 6	12	225541	1827	0	0.81%	100.00%
Case 7	12	106344	106344	70422	100.00%	33.78%
Case 8	36	70851	70850	16456	100.00%	76.77%
Case 9	36	40566	40566	12	100.00%	99.97%
EON						
Case 1	12	122937	0	0	0.00%	0.00%
Case 2	36*	128735	1	0	0.00%	100.00%
Case 3	1	16675	0	0	0.00%	0.00%
Case 4	36	65340	159	0	0.24%	100.00%
Case 5	36*	49246	49246	2074	100.00%	95.79%
Case 6	12	54835	54835	9	100.00%	99.98%
Case 7	36	20508	20508	5559	100.00%	72.89%
Case 8	36	31279	18166	0	58.08%	100.00%
Case 9	36*	16778	16778	337	100.00%	97.99%
GEANT2						
Case 1	36*	7984	0	0	0.00%	0.00%
Case 2	36*	8489	6462	0	76.12%	100.00%
Case 3	36	8837	8664	0	98.04%	100.00%
Case 4	36	2449	2449	0	100.00%	100.00%
Case 5	36	3713	3700	0	99.65%	100.00%
Case 6	12	3365	3359	0	99.82%	100.00%
Case 7	12	1580	1578	0	99.87%	100.00%
Case 8	12	1357	1357	0	100.00%	100.00%
Case 9	36	1628	1628	2	100.00%	99.88%

Table 4.13: Number of cycles done for every cases studied created. Number of greedy and local Search solutions unfeasible, and their percentage.

The table 4.13 shows the number of (i) total cycles, (ii) greedy unfeasible solutions and (iii) unfeasible solutions at the end of local search, for the configurations that have found the best solution on each case study. The last two columns shows the percentage of the unfeasible solution created by the Greedy algorithm, and the percentage of solutions turned feasible by the Local Search algorithm.

In the NSF network topology, the greedy algorithm did not generate any feasible solution in the cases T_3, T_7, T_8 and T_9. In the T_3 case, the local search was able to turn all of those solution feasible. The worst performance happened in case T_9 but, even in this case, it managed to turn feasible 55.00% of the greedy unfeasible solutions. In GBN network topology, the most difficult cases were T_7, T_8 and T_9. Here, the local search struggled with T_7 case only being able to turn feasible one third of the greedy unfeasible solutions. In EON network topology, the greedy algorithm did not generate any feasible solution in the cases T_5, T_6, T_7 and T_9. Here, the local search solved most of the cases and its worst result was in T_7 with a percentage of 72.89%. Finally, in the GEANT2 topology, the greedy solutions were almost all unfeasible (except T_1). On the other hand, local search algorithm only fail 2 times, in the process of turning feasible all given unfeasible solutions.

4.3.3 Multi-hop Grooming analysis

In this section, we aim to check if enabling multi-hop grooming helps in reducing the cost of the obtained solutions. Note that all client demands routed in this way have an impact in the cost of the solution since such demands just use the already placed OTUs. Figure 4.8 shows the percentage of 10 Gbps client demands groomed using multi-hop grooming for all case studies (these values were already presented in Table 4.10).

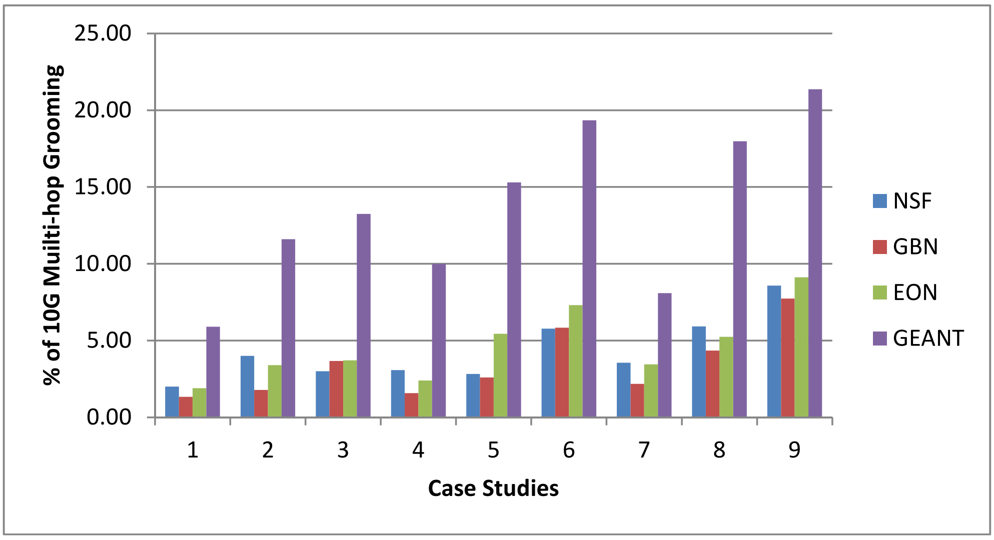


Figure 4.8: Percentage of $10GB/s$ traffic groomed using Multi-hop option.

The main conclusion is that multi-hop grooming is used by the algorithm to find the best solutions in all cases. Looking for the details, it is also shown that the use of multi-hop grooming grows with the traffic increase and with the reduction of the smaller client demands units. This happens because with more traffic there are more OTUs and therefore increasing the probability of the existence of more gaps. With the reduction of the smaller client demands units, the groomed units have a greater weight in the average. Looking at the number of units routed in the Table 4.10, the number of units groomed grows with the increase of traffic.

Note that the option of multi-hop grooming of traffic demands with $40Gb/s$ granularity is also possible. Nevertheless, it is difficult to happen since the creation of a $40Gb/s$ gap happens with low probability and the created gaps are always of 1 unit. Yet, there are some few cases where this happens, as shown in the T_9^{NSF} results (Table D.70).

4.3.4 Optical Elements

The numbers of optical elements in a network topology are directly related with the cost. Figure 4.9 shows the percentage distribution of optical elements in used in the best solution acquired.

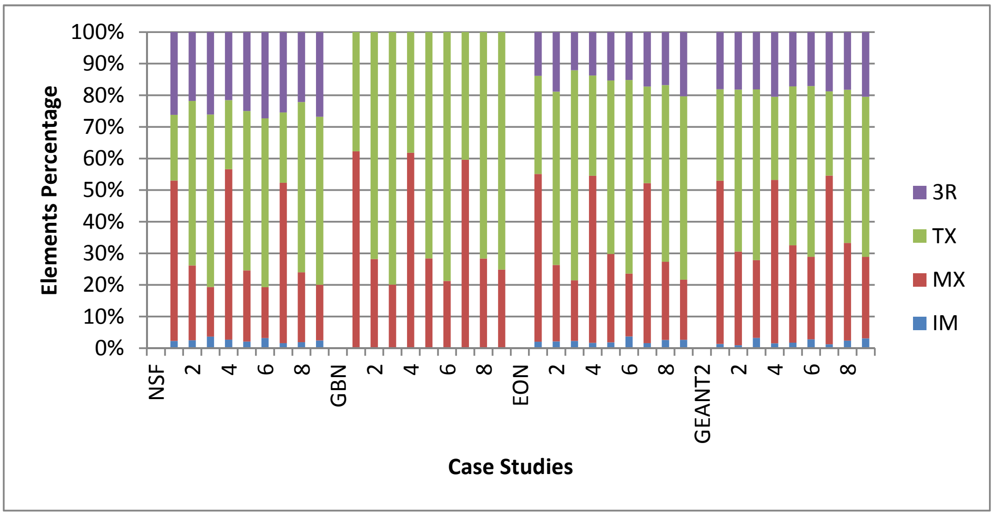
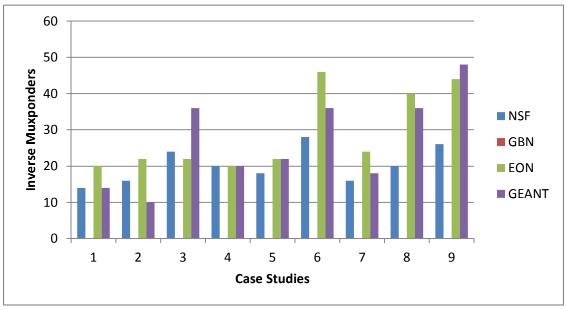


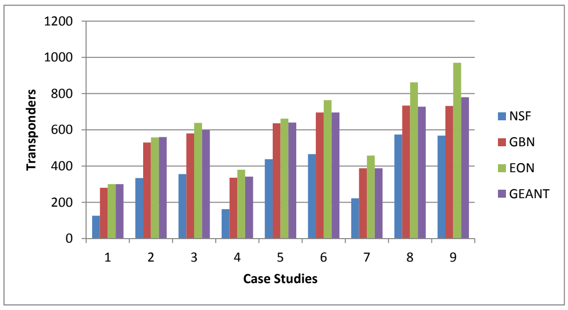
Figure 4.9: Graph showing the percentage of the different optical element used in the best solution, of the nine case studies, for all networks topologies.

This graph shows predominance number of transponders in all networks. In GBN network it is even greater, since it does not use 3R regenerators neither inverse muxponders. As seen in the cost analysis, the cases 1, 4 and 7 are the ones with the higher number of optical muxpondres, around 50% of total number of elements. Then, in cases 2, 5 and 8 the muxponders number reduce to near 30%, and the remaining cases reduces to around 20% (this values vary only slightly from network to network). The 3R regenerators represent about 20% of the number of optical elements, except, as seen the GBN network. Finally, the inverse muxponders represent a residual percentage within the total number of optical elements. Nevertheless, their use in the found solutions means that they effectively have an impact on the cost of the solutions.

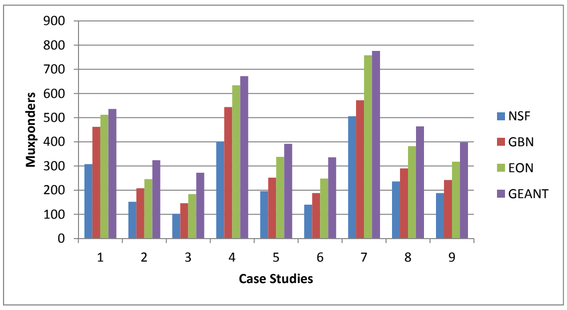
Figure 4.10 shows four sub-graphs with the number of OTU optical elements of the best solutions found for each case study. The elements are: a) Inverse Muxponders; b) Transponders; c) Muxponders; d) 3R Regenerators. In the first sub-graph a), it is visible that the EON



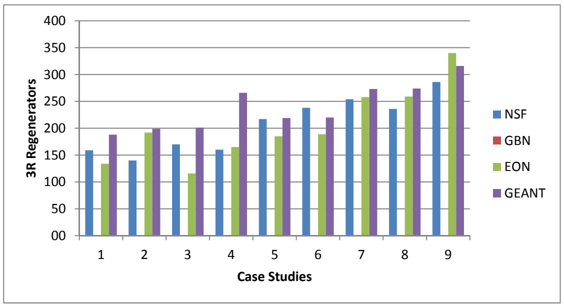
a) Number of Inverse Muxponders



b) Number of Transponders



c) Number of Muxponders



d)Number of 3R Regenerators

Figure 4.10: Number of OTN optical elements in the best solutions, for all networks topologies

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and GEANT2 are the networks with more inverse muxponders elements in their solutions. The sub-graph b) shows a constant grow behaviour. As expected with the growth of the client demand traffic, the number of transponders also increase. In sub-graph c), the number of muxponders increases with the growth of the traffic but decreases when the percentage of client traffic of lower granularity decreases. Note that the results of sub-graphs b) and c) are complementary: solutions with less transponders exhibit more muxponders and vice-versa. For example, in the T_1, T_2 and T_3 cases, the number of transponders increase from T_1 to T_3 while the number of Muxponders inversely decrease. This phenomenon is, once again, related with the number of small granularity traffic units in the cases studies. Finally, in sub-graph d), a slight increase on the number of regenerators is observed. This is related with the increasing total bandwidth B_{total}. As previously mentioned, GBN does not use this optical element in their solutions.

4.3.5 Spectrum Fragmentation on Fibers

Fragmentation of a fiber spectrum is a factor that measures the efficiency of channel assignment of the OTU created in the best solutions. Figure 4.11 shows the average and maximum fiber fragmentation, created by channel assignment. Here, a relatively constant average fiber fragmentation is shown among all networks topologies. The channel assignment task has produced a similar average fragmentation value for the nine cases of each network topology, showing that the results are not much influenced by the different traffic matrices. The GEANT network has the highest average fiber fragmentation since it is the biggest network topology and, therefore, the one with more fragmentation gaps. GEANT is also the network that has the highest maximum fiber fragmentation. On the other hand, the GBN

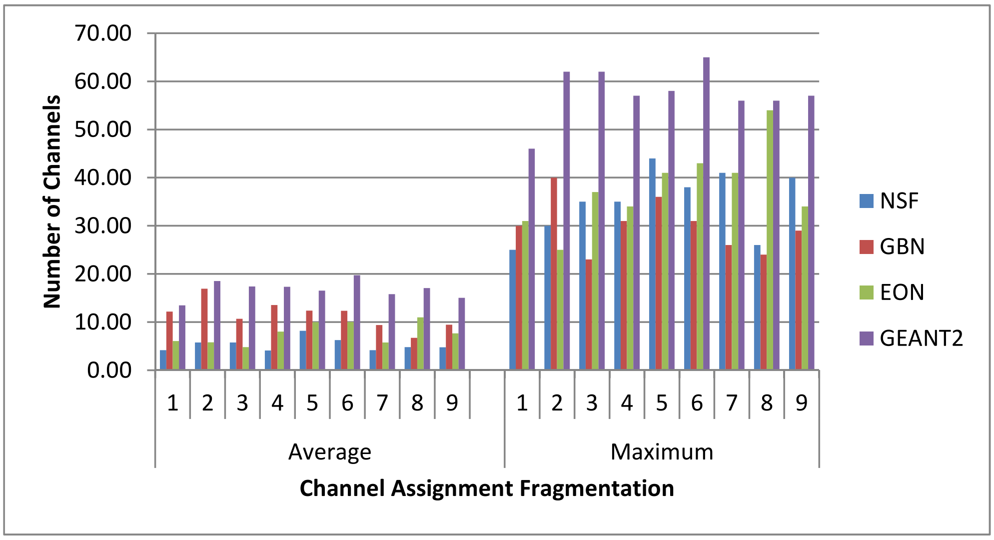

Figure 4.11: Graph showing the average number of fiber fragmentation and its correspondent maximum value.

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also shows a higher number of average fiber fragmentation. In this network, the solution does not use 3R regenerators. Therefore, when an OTU is routed through many links, it forces the assignment of WDM channels to have the same number in all those link, causing high fragmented solutions.

The maximum values for the fiber fragmentation are very much influenced by the network topology characteristics like average link lengths or average degree (*i.e.*, ratio between number of links and number of nodes). For example, if a given network has a link that is almost unused (let's say, only two OTUs use it), the probability of such link imposing a large maximum fiber fragmentation value is high.

4.4 Conclusion

This chapter has shown that the multi-thread approach, exploited in the developed algorithm, is highly beneficial in the efficiency of the algorithm. The computational experiments, running on a computational platform with 12 cores, showed a gain around 10 when 12 threads are used compared with a standard single thread approach. Therefore, using the multi-thread approach increases the probability of finding better solutions using the same amount of computational time. Moreover, two alternatives were tested for the solution memory approach (with and without shared memory) and the trade off between them was evaluated.

The ability of the algorithm to compute feasible solutions when the traffic matrices require heavy loaded networks was also evaluated. In such cases, we had to let the Greedy algorithm to generate unfeasible solutions and we have implemented the Local Search dealing with this fact. The computational results showed that the Local Search was able to turn feasible most of the unfeasible solutions generated by the Greedy algorithm.

The solutions were analysed in terms of executed number cycles, cost and maximum assigned channel, cost percentage of the different optical elements, multi-hop grooming and spectrum fragmentation. This analysis was conducted in four well known network topologies and with nine case studies created for each topology. From this analysis, the developed optimization algorithm was evaluated. With this analysis, some conclusions could be obtained about the influence of the type of network topology and traffic demands on the characteristics of the best solutions. For example, it was shown that multi-hop grooming is used in the best solutions found by the algorithm in almost all cases studies (the exception was the GBN network topology).

Chapter 5

Conclusions

5.1 Summary

In this dissertation, a very complex OTN network design problem was addressed. The problem consists in the determination of an appropriate minimum cost set of OTUs capable of supporting a given set of client demands on a given fibre network. The cost of a solution was based of the costs of electrical-optical components assuming that the all-optical component costs are negligible. The problem is very complex because it involves a lot of different issues enabled by the OTN technology. First, different type of client demands and different line rates in OTUs were considered. Then, besides single hop grooming, the problem also considers the possibility of multi-hop grooming. Then, the problem considers the use of inverse-multiplexing of client demands on lower rate OTUs. Then, the problem limits the 3R regenerator placement to intermediate nodes. Finally, besides cost, the problem also considers the minimization of the maximum assigned WDM channel.

To address this very complex optimization problem, a heuristic has been developed. The algorithm solution is based on some standard approaches but it also includes non standard features.

Let us first describe the standard approaches. The algorithm is based on a standard multi-start local search meta-heuristic. In the adopted meta-heuristic, the algorithm accepts non feasible solutions at the end of the Greedy step and let the Local Search turn them feasible. The computational results showed the correctness of this decision for the most demanding case studies where the Greedy step could hardly find any feasible solution but where the Local Search was able to turn feasible a significant percentage of them. To compute a solution, first the routing problem is addressed aiming to minimize the cost and, separately, a channel assignment task is executed aiming to minimize the maximum assigned WDM channel. The channel assignment task is also based on a standard heuristic.

Let us now describe the non standard approaches. In this algorithm, instead of working with a pre-computed set of candidate paths (the common approach of almost all works on this subject), which are usually given by a k-shortest path algorithm, a non-standard shortest path algorithm is used whenever a path is required for a new OTU. This has the main advantage of not taking out from the search any feasible solution. I believe that the non-standard shortest path algorithms are also very different from other works. The multi-thread approach is the main non standard feature. In particular, the shared memory mechanism is a proposal that saves the computation of threads: they run the channel assignment task only if it is worthwhile (*i.e.*, only when their solution is potentially better then the one in the shared memory). The computational results showed a drastic improvement in the quality of the best solutions found since it is able to use the full CPU capacity of the computational platform.

As a final remark, to validate the efficiency of the developed optimization tool, the case studies were defined using existing network topologies with many different characteristics and for sets of client demands also with many different characteristics. The different case studies illustrate the usefulness of the tool as a valuable means to study the characteristics of good design solutions for any case study of interest.

This work has already produced a paper entitled "Algorithms in the deployment of Optical Transport Networks", that was presented in the $15th$ International Conference on Transparent Optical Networks (ICTON), in June 2013 [15].

5.2 Future Work

The realization of this work enabled the identification of some possible future research issues of interest. Such issues are the following:

- **Flex-grid Network Design Solution -** Flex-grid OTN technology is becoming very important. In another M.Sc. dissertation, that run in parallel with this work [16], an optimization algorithm similar to the one proposed here is presented for the Flex-grid case. Nevertheless, that algorithm is based on pre-computed candidate paths. Therefore, it would be useful to adapt the algorithm presented in this dissertation for the Flex-grid technology, in order to evaluate the possible cost reduction of solutions when this technology became available.

- **Algorithm Termination Criteria -** In this work, the stopping criteria is very simple, *i.e.*, the algorithm stops after reaching a predefined runtime limit. A more intelligent stopping criteria can be possible making use of the multi-thread approach (for example, when most of the threads reach the same best solution). Such idea should be investigated to determine if it is worthwhile.

- **Energy Consumption -** An issue that is becoming very important is energy consumption. This topic is now a real factor of decision between elements of optical networks, because one equipment can be more expensive but the energy consumption may cover the extra cost. In this case, the aim could be to determine a network configuration that minimizes the consumed energy instead of minimizing the cost. It seems easy to adapt the proposed algorithm for this new objective function. Nevertheless, it requires further research.

- **Network Restoration -** The Network restoration refers to the ability of a network to restore or recover from a failure. This characteristic can represent a cost increase but the restoration is a desirable capacity for the Networks. Note that restoration is a very complex issue and an easy adaptation of this algorithm is hard to think. Therefore, serious research is required in this matter.

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Appendix A

Input File

This appendix shows the input file of the first case of NSFNET network. The last information is the penalty applied in every through node.

N node	N links		
14	20		
Ni	Nf	km	Cap
1	4	1136	80
1	11	1702	80
2	3	596	80
2	5	2349	80
2	10	789	80
3	9	366	80
3	14	385	80
4	5	959	80
4	11	683	80
5	6	573	80
6	7	732	80
6	12	1450	80
7	8	718	80
8	9	706	80
9	10	451	80
9	13	839	80
10	14	246	80
11	12	2049	80
12	13	1128	80
12	14	1976	80

N Demands

30

Ni	Nf	10	40	100
1	2	15	2	0
1	7	16	3	1
1	8	20	1	0
1	9	22	2	1
2	3	20	3	0
2	7	30	2	2
2	9	15	2	1
2	11	31	0	0
2	14	12	2	1
3	5	14	3	0
3	8	18	1	2
3	9	20	1	0
3	11	24	1	1
3	13	21	1	1
3	14	26	2	1
4	11	24	1	1
4	12	19	2	1
4	13	23	1	0
5	6	21	1	0
5	9	25	3	0
5	13	26	0	1
6	13	15	1	1
7	10	15	1	1
8	11	20	1	0
8	12	25	0	1
8	14	15	5	0
9	10	15	2	0
9	11	21	1	2
9	14	15	3	0
13	14	17	2	1

OTU Types

3

Gbits	Width	3R	dis(km)	Tx	Mx	Mx2	IMx
40	50.0	9.6	2500	6	5	0	0
100	50.0	24	2000	15	16	13	20
100	75.0	35.2	2500	22	19	16	23

Penalty

160

Appendix B

Output Solution

Here we present the output from the execution of the first case of NSFNET network, with 8 thread during 60 seconds.

```
CAPACITY:
  0   1   2   3   4   5   6   7   8   9  10  11  12  13  14
  1   x   x   x  33   x   x   x   x   x   x   0   x   x   x
  2   x   x  19   x  21   x   x   x   x  18   x   x   x   x
  3   x  19   x   x   x   x   x   x  37   x   x   x   x  31
  4  33   x   x   x  48   x   x   x   x   x  36   x   x   x
  5   x  21   x  48   x  59   x   x   x   x   x   x   x   x
  6   x   x   x   x  59   x  49   x   x   x   x  23   x   x
  7   x   x   x   x   x  49   x  54   x   x   x   x   x   x
  8   x   x   x   x   x   x  54   x  52   x   x   x   x   x
  9   x   x  37   x   x   x   x  52   x  36   x   x  27   x
 10   x  18   x   x   x   x   x   x  36   x   x   x   x  24
 11   0   x   x  36   x   x   x   x   x   x   x  36   x   x
 12   x   x   x   x   x  23   x   x   x   x  36   x  34  10
 13   x   x   x   x   x   x   x   x  27   x   x  34   x   x
 14   x   x  31   x   x   x   x   x   x  24   x  10   x   x
```

DEMANDS:

Indic	Ni	Nf	10	40	100	N...										
0	9	14	15	0	0	1	46	15								
1	2	9	0	2	0	1	19	2								
2	4	13	0	1	0	1	20	1								
3	5	13	26	0	0	3	55	2	50	2	74	24				
4	3	5	0	3	0	1	21	3								
5	3	11	24	0	0	1	48	24								
6	7	10	0	1	0	1	22	1								
7	2	7	0	0	2	1	1	2								
8	3	8	0	0	2	1	2	2								
9	2	11	31	0	0	1	49	31								
10	5	6	21	0	0	1	50	21								
11	2	7	30	0	0	1	51	30								
12	9	14	0	3	0	1	23	3								
13	3	11	0	0	1	1	3	1								
14	13	14	0	0	1	1	4	1								
15	8	11	20	0	0	1	52	20								
16	4	12	0	2	0	1	24	2								
17	1	2	15	0	0	1	53	15								
18	1	8	0	1	0	1	25	1								
19	1	7	0	0	1	1	5	1								
20	1	9	0	0	1	1	6	1								
21	4	13	23	0	0	1	54	23								
22	3	13	0	0	1	1	7	1								
23	6	13	0	0	1	1	8	1								
24	9	11	21	0	0	3	49	1	56	1	64	20				
25	2	3	0	3	0	1	26	3								
26	1	9	22	0	0	1	47	22								
27	1	7	16	0	0	1	57	16								
28	2	14	12	0	0	1	58	12								
29	2	7	0	2	0	1	27	2								
30	3	9	0	1	0	1	28	1								
31	3	14	0	2	0	1	29	2								
32	3	13	21	0	0	1	59	21								
33	5	6	0	1	0	1	30	1								
34	4	11	0	1	0	1	31	1								
35	9	10	15	0	0	1	60	15								
36	7	10	15	0	0	1	61	15								
37	5	13	0	0	1	1	9	1								
38	1	7	0	3	0	1	32	3								
39	8	14	15	0	0	1	62	15								
40	1	9	0	2	0	1	33	2								
41	3	8	18	0	0	1	63	18								
42	8	14	0	5	0	1	34	5								
43	3	5	14	0	0	1	66	14								
44	7	10	0	0	1	1	10	1								
45	2	14	0	0	1	1	11	1								
46	13	14	17	0	0	4	62	1	63	1	59	1	65	16		
47	5	9	25	0	0	3	73	1	66	1	75	24				
48	2	3	20	0	0	1	67	20								
49	4	12	19	0	0	1	68	19								
50	1	8	20	0	0	1	69	20								
51	13	14	0	2	0	1	35	2								
52	9	11	0	1	0	1	36	1								
53	6	13	0	1	0	1	37	1								
54	1	2	0	2	0	1	38	2								
55	3	8	0	1	0	1	39	1								
56	8	12	0	0	1	1	12	1								
57	3	14	26	0	0	1	70	26								
58	2	9	0	0	1	1	13	1								
59	9	11	0	0	2	2	14	1	15	1						
60	3	13	0	1	0	1	40	1								
61	8	11	0	1	0	1	41	1								
62	2	14	0	2	0	1	42	2								
63	4	11	24	0	0	1	71	24								
64	5	9	0	3	0	1	43	3								
65	4	11	0	0	1	1	16	1								
66	9	10	0	2	0	1	44	2								
67	8	12	25	0	0	5	68	1	54	1	59	1	63	1	76	24
68	3	9	20	0	0	3	46	1	70	1	73	19				
69	3	14	0	0	1	1	17	1								
70	4	12	0	0	1	1	18	1								
71	3	11	0	1	0	1	45	1								
72	2	9	15	0	0	1	56	15								
73	6	13	15	0	0	5	55	2	59	1	66	1	50	1	72	12

Ind	O	D	Ty1	Ty2	S	Notu	Nn	N3R	...										
76	0	0	0	0	0	0	0	0	0	0	0	0	0	0					
1	2	7	100	100	0	2	5	1	7	8	9	3	2	8				||	1 7
2	3	8	100	100	0	2	3	0	8	9	3							||	1 8
3	3	11	40	100	0	3	4	2	11	12	14	3	12	14				||	1 13
4	13	14	100	100	0	1	4	0	14	10	9	13						||	1 14
5	1	7	40	100	0	3	5	1	7	6	5	4	1	5				||	1 19
6	1	9	40	100	0	3	7	2	9	8	7	6	5	4	1	8	5	||	1 20
7	3	13	100	100	0	1	3	0	13	9	3							||	1 22
8	6	13	100	100	0	1	3	1	13	12	6	12						||	1 23
9	5	13	40	100	0	3	4	1	13	12	6	5	12					||	1 37
10	7	10	40	100	0	3	4	0	10	9	8	7						||	1 44
11	2	14	100	100	0	1	3	0	14	10	2							||	1 45
12	8	12	100	100	0	1	4	1	12	6	7	8	6					||	1 56
13	2	9	100	100	0	1	3	0	9	10	2							||	1 58
14	9	11	40	100	0	3	4	1	11	12	13	9	12					||	1 59
15	9	11	40	100	0	3	4	1	11	12	13	9	12					||	1 59
16	4	11	100	100	0	1	2	0	11	4								||	1 65
17	3	14	100	100	0	1	4	0	14	10	2	3						||	1 69
18	4	12	100	100	0	1	4	1	12	6	5	4	6					||	1 70
19	2	9	40	40	0	2	3	0	9	3	2							||	1 1
20	4	13	40	40	0	1	4	2	13	12	11	4	12	11				||	1 2
21	3	5	40	40	0	3	5	1	5	2	10	14	3	2				||	1 4
22	7	10	40	40	0	1	4	0	10	9	8	7						||	1 6
23	9	14	40	40	0	3	3	0	14	10	9							||	1 12
24	4	12	40	40	0	2	3	1	12	11	4	11						||	1 16
25	1	8	40	40	0	1	6	1	8	7	6	5	4	1	5			||	1 18
26	2	3	40	40	0	3	2	0	3	2								||	1 25
27	2	7	40	40	0	2	5	1	7	8	9	3	2	8				||	1 29
28	3	9	40	40	0	1	2	0	9	3								||	1 30
29	3	14	40	40	0	2	2	0	14	3								||	1 31
30	5	6	40	40	0	1	2	0	6	5								||	1 33
31	4	11	40	40	0	1	2	0	11	4								||	1 34
32	1	7	40	40	0	3	5	1	7	6	5	4	1	5				||	1 38
33	1	9	40	40	0	2	7	2	9	8	7	6	5	4	1	8	5	||	1 40
34	8	14	40	40	0	5	4	0	14	3	9	8						||	1 42
35	13	14	40	40	0	2	4	0	14	10	9	13						||	1 51
36	9	11	40	40	0	1	4	1	11	12	13	9	12					||	1 52
37	6	13	40	40	0	1	3	1	13	12	6	12						||	1 53
38	1	2	40	40	0	2	4	1	2	5	4	1	5					||	1 54
39	3	8	40	40	0	1	3	0	8	9	3							||	1 55
40	3	13	40	40	0	1	3	0	13	9	3							||	1 60
41	8	11	40	40	0	1	6	1	11	4	5	6	7	8	5			||	1 61
42	2	14	40	40	0	2	3	0	14	10	2							||	1 62
43	5	9	40	40	0	3	5	1	9	8	7	6	5	8				||	1 64
44	9	10	40	40	0	2	2	0	10	9								||	1 66
45	3	11	40	40	0	1	4	2	11	12	14	3	12	14				||	1 71
46	9	14	40	10	0	4	3	0	14	10	9							||	2 0 68
47	1	9	40	10	2	6	7	2	9	8	7	6	5	4	1	8	5	||	1 26
48	3	11	40	10	0	6	4	2	11	12	14	3	12	14				||	1 5
49	2	11	40	10	0	8	4	1	11	4	5	2	5					||	2 9 24
50	5	6	40	10	0	6	2	0	6	5								||	3 10 3 73
51	2	7	100	10	0	3	5	1	7	8	9	10	2	9				||	1 11
52	8	11	40	10	0	5	6	1	11	4	5	6	7	8	5			||	1 15
53	1	2	40	10	1	4	4	1	2	5	4	1	5					||	1 17
54	4	13	40	10	0	6	4	2	13	12	11	4	12	11				||	2 21 67
55	6	13	40	10	0	1	3	1	13	12	6	12						||	2 3 73
56	2	9	40	10	0	4	3	0	9	10	2							||	2 72 24
57	1	7	40	10	0	4	5	1	7	6	5	4	1	5				||	1 27
58	2	14	40	10	0	3	3	0	14	10	2							||	1 28
59	3	13	40	10	0	6	3	0	13	9	3							||	4 32 46 73 67
60	9	10	40	10	1	4	2	0	10	9								||	1 35
61	7	10	40	10	1	4	4	0	10	9	8	7						||	1 36
62	8	14	40	10	0	4	4	0	14	3	9	8						||	2 39 46
63	3	8	40	10	0	5	3	0	8	9	3							||	3 41 46 67
64	9	11	40	10	0	5	4	1	11	12	13	9	12					||	1 24
65	13	14	40	10	0	4	4	0	14	10	9	13						||	1 46
66	3	5	40	10	0	4	3	1	5	2	3	2						||	3 43 47 73
67	2	3	40	10	0	5	2	0	3	2								||	1 48
68	4	12	40	10	0	5	3	1	12	11	4	11						||	2 49 67
69	1	8	40	10	0	5	6	1	8	7	6	5	4	1	5			||	1 50
70	3	14	40	10	1	7	2	0	14	3								||	2 57 68
71	4	11	40	10	0	6	2	0	11	4								||	1 63
72	6	13	40	10	0	3	3	1	13	12	6	12						||	1 73
73	3	9	40	10	0	5	2	0	9	3								||	2 68 47
74	5	13	40	10	0	6	4	1	13	12	6	5	12					||	1 3
75	5	9	40	10	0	6	5	1	9	8	7	6	5	8				||	1 47
76	8	12	40	10	0	6	4	1	12	6	7	8	6					||	1 67

Channel assignment Plan 0

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	x	x	x	33	x	x	x	x	x	x	0	x	x	x
2	x	x	19	x	21	x	x	x	x	18	x	x	x	x
3	x	19	x	x	x	x	x	x	37	x	x	x	x	31
4	33	x	x	x	48	x	x	x	x	x	36	x	x	x
5	x	21	x	48	x	59	x	x	x	x	x	x	x	x
6	x	x	x	x	59	x	49	x	x	x	x	23	x	x
7	x	x	x	x	x	49	x	54	x	x	x	x	x	x
8	x	x	x	x	x	x	54	x	52	x	x	x	x	x
9	x	x	37	x	x	x	x	52	x	36	x	x	27	x
10	x	18	x	x	x	x	x	x	36	x	x	x	x	24
11	0	x	x	36	x	x	x	x	x	x	x	36	x	x
12	x	x	x	x	x	23	x	x	x	x	36	x	34	10
13	x	x	x	x	x	x	x	x	27	x	x	34	x	x
14	x	x	31	x	x	x	x	x	x	24	x	10	x	x

```
Number of threads        : 8
Execution time           : 60.082
Solution cost            : 4440.4
Hight slot assigned      : 59
Solution found at        : 2.277
N Iterations             : 30320
Invalid Slot assigned    : 0
N of greedy unfeasible   : 0
N of LS unfeasible       : 0
Unfeasible degree        : 0
N inverse Multiplex      : 14
Cost inverse Multiplex   : 6.31 %
Cost inverse Multiplex   : 2800
N Muxponders             : 300
Cost Muxponders          : 34.86 %
Cost Muxponders          : 15480
N transponders           : 126
Cost transponders        : 22.30 %
Cost transponders        : 9900
N 3R                     : 157
cost 3R                  : 36.53 %
cost 3R                  : 16224
10G Multi-Hop Grooming   : 8
10G Multi-Hop Grooming   : 1.33 %
40G Multi-Hop Grooming   : 0
40G Multi-Hop Grooming   : 0.00 %
Mean Fragmentation       : 4.5
Max Fragmentation        : 28
```

Appendix C

Case Studies

C.1 GEANT2

Table C.1: GEANT 2 - Case 1

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	2	7	3	0	5	19	14	2	0	10	17	7	0	0	18	27	5	2	1
1	7	4	2	0	5	21	5	0	0	10	19	8	1	0	18	31	4	0	1
1	15	7	0	0	5	27	1	0	0	10	25	4	1	0	19	20	1	2	0
1	16	6	2	0	6	7	7	1	0	10	28	6	2	1	19	24	3	1	0
1	17	5	0	1	6	9	2	0	0	10	29	4	1	1	19	27	7	0	0
1	19	8	1	1	6	13	6	4	0	11	13	9	1	0	19	29	6	3	1
1	22	8	2	0	6	14	7	3	0	11	24	3	1	0	20	22	9	0	0
1	24	2	0	1	6	16	5	0	0	11	25	6	2	0	20	23	6	0	0
1	25	4	0	0	6	17	8	0	0	11	29	4	2	0	20	26	8	1	0
1	31	6	0	1	6	23	8	1	0	11	30	8	1	0	20	27	5	0	0
1	32	10	0	0	6	24	7	2	0	11	31	8	1	0	20	30	6	1	0
2	3	5	1	1	6	25	11	0	1	12	15	10	1	0	20	32	6	1	0
2	7	11	0	0	6	28	6	0	0	12	16	5	0	0	21	26	5	1	1
2	12	6	0	0	6	29	8	1	1	12	18	4	0	0	21	27	6	1	0
2	17	9	2	0	6	31	10	0	0	12	22	5	1	1	21	29	3	3	0
2	18	9	1	0	7	8	7	1	0	12	24	6	0	1	21	30	4	1	0
2	22	7	0	0	7	9	5	0	0	12	26	8	0	0	22	23	4	0	0
2	23	3	0	1	7	10	2	1	0	13	18	6	0	0	22	24	6	0	0
2	28	2	1	0	7	11	10	0	0	13	27	5	0	0	22	25	8	0	2
2	32	9	1	0	7	14	3	1	0	14	18	2	1	1	22	26	10	1	0
3	5	3	1	0	7	17	5	0	0	14	19	4	1	0	22	27	6	0	0
3	8	3	0	1	7	22	9	2	1	14	20	6	1	1	22	31	7	0	2
3	11	6	0	0	7	24	8	1	1	14	21	8	1	0	23	25	7	1	0
3	13	8	0	1	7	28	6	0	0	14	22	11	1	1	23	29	9	0	0
3	14	10	0	0	7	29	7	0	0	14	29	5	0	0	23	31	4	0	1
3	15	6	1	0	7	30	2	1	0	14	30	5	1	0	23	32	5	2	0
3	17	9	0	0	8	12	6	0	0	15	22	5	1	0	24	25	9	1	0
3	20	4	1	1	8	14	3	0	0	15	24	7	2	0	24	26	6	0	0
3	21	2	1	0	8	18	6	2	0	15	28	5	2	0	24	30	9	0	1
3	22	12	1	0	8	20	8	0	0	15	29	6	0	0	24	32	3	0	0
3	23	5	0	1	8	32	5	0	0	15	30	6	0	0	25	26	7	0	0
3	27	6	2	0	9	10	4	2	0	16	17	6	1	0	25	30	5	0	0
3	30	6	0	0	9	11	6	0	0	16	18	1	0	0	26	28	5	1	0
4	5	5	0	1	9	13	2	1	1	16	20	5	1	1	26	31	4	1	0
4	7	12	0	0	9	14	7	2	0	16	27	6	0	0	28	31	2	1	0

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Table C.1 – *Continued from previous page*

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
4	8	5	0	0	9	15	10	0	0	16	29	7	0	0	28	32	8	1	0
4	16	4	2	0	9	17	5	0	0	17	20	6	1	0	29	31	7	1	0
4	24	7	1	0	9	19	3	0	0	17	28	6	0	0	29	32	9	1	0
4	28	7	4	0	9	20	1	2	0	17	29	10	0	0	30	32	3	1	0
4	29	4	1	0	9	21	6	0	1	18	22	8	0	0					
4	32	5	0	0	9	29	8	0	0	18	24	7	0	0					
5	12	6	0	0	10	14	4	1	2	18	26	9	0	0					

Table C.2: GEANT 2 - Case 2

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	3	4	1	0	5	16	3	1	0	10	12	3	2	0	17	27	1	2	0
1	4	7	3	1	5	18	5	2	1	10	15	5	1	1	17	30	2	3	0
1	10	6	1	0	5	20	3	3	0	10	17	2	2	0	17	31	0	1	0
1	17	1	3	0	5	21	3	1	0	10	18	2	2	0	18	20	3	1	0
1	19	4	0	0	5	27	5	2	0	10	27	4	3	0	18	26	3	1	1
1	21	1	3	0	5	28	6	3	0	10	32	4	1	0	18	30	1	4	0
1	25	2	0	0	5	31	1	2	0	11	13	6	2	0	19	27	4	1	0
1	29	3	1	1	6	8	4	0	0	11	15	1	3	0	19	30	3	4	0
1	30	3	3	0	6	10	3	2	0	11	18	2	1	1	19	31	5	1	0
1	31	4	0	0	6	14	7	1	0	11	21	1	1	0	20	23	2	2	0
2	12	4	0	0	6	15	4	1	0	11	24	2	1	3	20	26	4	0	0
2	14	4	2	1	6	17	4	2	1	11	25	5	2	2	20	28	2	1	0
2	15	3	1	1	6	18	2	0	0	11	29	3	5	0	20	29	1	1	0
2	16	4	0	0	6	25	0	2	0	12	13	2	2	0	20	32	4	1	0
2	18	3	1	0	6	26	4	2	0	12	16	3	2	0	21	23	1	1	0
2	21	3	2	0	6	28	2	3	0	12	20	7	0	0	21	24	7	3	0
2	24	1	2	0	7	8	5	1	0	12	21	3	1	0	21	25	2	2	0
2	25	3	1	0	7	9	2	1	0	12	28	2	2	0	21	31	7	2	0
2	26	3	1	0	7	12	3	0	0	12	30	3	0	0	22	23	2	1	0
2	29	2	1	0	7	13	2	2	0	12	31	2	1	0	22	25	3	0	0
2	30	1	4	0	7	15	1	0	1	13	14	0	0	0	22	26	4	1	0
3	4	4	2	1	7	20	2	2	0	13	18	3	0	0	22	28	2	0	1
3	6	2	2	0	7	22	3	2	0	13	23	1	3	0	22	30	4	3	0
3	10	5	1	0	7	26	2	3	0	13	27	6	2	0	23	25	5	1	0
3	11	1	2	0	7	27	3	2	0	14	17	4	0	0	23	26	5	1	0
3	17	4	0	0	7	28	4	2	0	14	21	1	1	0	24	25	2	1	0
3	19	2	3	0	7	29	2	3	1	14	23	0	0	1	24	26	4	1	0
3	21	0	0	0	8	12	3	0	1	14	26	2	3	2	24	28	3	1	0
3	22	1	3	1	8	14	3	1	0	14	29	2	4	2	24	31	6	0	1
3	23	2	2	1	8	17	2	2	0	14	30	0	3	0	25	28	2	2	1
3	26	5	1	0	8	24	4	1	0	14	32	3	0	0	25	29	0	2	0
3	27	4	1	1	8	25	4	0	0	15	17	3	1	0	25	30	2	1	0
4	9	4	2	0	8	26	7	3	0	15	27	2	2	0	26	27	2	2	0
4	11	5	1	1	8	28	2	1	0	15	28	2	2	0	26	29	4	4	0
4	13	7	2	0	8	29	2	1	0	15	32	3	2	0	26	30	3	2	0
4	17	4	0	0	8	31	0	1	0	16	19	3	1	0	27	31	1	0	0
4	25	5	2	0	8	32	8	0	2	16	20	3	2	0	29	32	6	3	0
4	26	3	2	0	9	10	1	1	1	16	26	3	1	1	30	31	3	2	0
4	28	3	0	0	9	15	3	0	0	16	27	3	2	0	30	32	5	0	0
4	31	1	1	1	9	20	4	3	0	16	28	0	2	0					
5	12	3	4	0	9	28	2	1	0	16	30	4	0	0					
5	13	5	1	0	9	29	2	2	0	17	18	2	2	2					

Table C.3: GEANT 2 - Case 3

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	3	2	2	1	4	21	2	3	0	9	16	1	1	0	16	25	2	1	0
1	5	3	2	1	4	24	4	2	1	9	17	2	0	1	16	26	2	2	1
1	7	3	2	0	4	27	2	1	0	9	19	1	1	0	16	27	4	1	2
1	8	6	2	0	4	28	1	3	1	9	22	2	1	0	17	24	2	1	1
1	9	2	0	0	4	31	1	1	1	9	23	5	1	3	17	26	1	1	0
1	10	4	1	0	4	32	2	3	0	9	26	2	2	1	17	30	2	0	0
1	13	1	0	1	5	8	2	2	0	10	19	0	2	1	17	32	2	2	0
1	14	2	2	1	5	10	3	2	2	10	22	1	2	0	18	19	3	4	0
1	15	2	2	1	5	11	3	0	0	10	24	3	1	0	18	22	3	1	1
1	18	0	1	0	5	23	4	4	0	10	26	4	1	1	18	26	3	2	1
1	19	6	3	1	5	24	3	1	0	11	13	1	3	3	18	31	3	0	2
1	22	1	1	0	5	25	2	1	0	11	15	0	1	1	18	32	5	1	0
1	25	3	1	0	5	26	1	1	0	11	19	2	2	1	19	21	3	2	0
1	27	1	0	0	5	27	2	1	0	11	20	3	1	0	19	22	6	1	0
1	31	1	1	0	5	28	1	1	1	11	21	1	0	1	19	23	4	1	0
2	4	0	0	1	5	29	2	3	0	11	23	4	4	0	19	24	1	2	0
2	5	3	1	1	5	30	6	1	0	11	24	3	1	0	20	22	4	3	0
2	6	2	1	1	5	32	1	5	0	11	25	1	4	0	20	31	1	3	1
2	7	2	4	1	6	10	3	0	1	12	14	0	3	0	20	32	1	4	0
2	13	3	1	0	6	11	3	1	1	12	17	3	1	0	21	22	1	2	0
2	19	2	0	0	6	13	4	0	1	12	20	1	0	0	21	23	2	2	0
2	22	3	2	0	6	14	1	1	0	12	23	0	2	1	21	30	1	0	0
2	25	6	2	0	6	15	1	1	0	13	15	1	0	1	21	31	0	1	1
2	30	3	3	0	6	21	3	2	0	13	16	4	0	1	22	23	1	2	0
2	31	0	1	0	6	22	3	0	0	13	21	0	1	0	22	27	1	2	0
3	5	1	0	2	6	23	3	4	0	13	31	4	0	1	22	29	1	2	2
3	6	3	4	0	6	25	5	1	0	13	32	6	0	0	23	24	3	1	0
3	7	5	3	0	6	29	3	1	0	14	16	2	1	0	23	27	2	2	0
3	12	1	1	0	6	31	3	0	0	14	17	2	1	0	23	30	3	2	1
3	13	3	2	1	6	32	2	0	1	14	27	2	0	0	23	32	4	2	0
3	15	0	1	0	7	9	2	0	0	14	28	0	1	0	24	29	3	3	0
3	17	2	0	0	7	14	3	3	0	14	31	1	7	0	24	32	2	0	0
3	18	2	1	0	7	24	3	1	0	15	20	3	0	0	25	32	3	1	0
3	20	4	3	1	8	12	4	1	1	15	22	1	1	1	26	28	1	2	0
3	22	2	0	0	8	15	5	0	0	15	23	6	0	0	28	29	2	2	2
3	26	1	1	0	8	16	5	0	0	15	25	2	0	1	28	30	3	1	1
3	31	3	2	2	8	21	3	3	1	15	29	2	0	0	29	30	7	1	1
3	32	2	4	0	8	28	3	2	0	16	17	0	6	0	30	31	1	3	0
4	5	4	2	0	8	31	4	5	1	16	19	3	1	1	31	32	1	3	0
4	10	2	1	0	9	12	1	2	0	16	20	2	0	0					
4	15	4	1	0	9	14	5	1	0	16	21	2	0	0					
4	16	3	3	1	9	15	2	2	0	16	22	4	1	0					

Table C.4: GEANT 2 - Case 4

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	3	6	1	0	5	11	7	0	0	10	12	7	0	0	17	18	6	1	0
1	9	5	1	0	5	15	5	1	0	10	14	8	1	0	17	21	4	1	0
1	12	5	1	0	5	18	3	0	0	10	15	5	0	1	17	27	8	1	0
1	13	4	0	0	5	20	3	1	0	10	17	5	2	0	17	28	6	0	0
1	14	8	0	0	5	22	4	1	1	10	18	3	1	0	17	29	4	3	0
1	15	6	0	0	5	23	2	2	0	10	19	4	0	0	17	30	2	0	0
1	18	6	1	0	5	24	5	1	0	10	20	7	0	0	18	20	3	1	0
1	19	3	0	0	5	25	5	1	0	10	21	8	0	0	18	21	5	1	0
1	22	3	1	0	5	27	1	0	0	10	23	1	1	0	18	23	5	0	1
1	23	2	1	1	5	28	4	0	0	10	26	2	1	0	18	24	1	0	0
1	24	3	0	0	5	29	3	2	0	11	13	3	2	0	18	25	7	2	1
1	25	7	0	0	5	30	3	0	1	11	14	5	0	0	18	26	2	2	1
1	27	8	1	0	5	32	3	0	0	11	18	4	0	1	19	21	3	0	0
1	29	4	1	0	6	11	4	2	0	11	20	1	1	1	19	23	5	0	0
1	31	5	1	0	6	12	8	0	0	11	21	1	0	0	19	25	6	0	0
2	4	4	1	0	6	13	7	0	0	11	25	10	1	0	19	26	3	1	0
2	6	2	0	0	6	14	2	3	0	11	26	7	0	0	19	28	6	1	0
2	8	9	0	0	6	15	6	1	0	11	29	4	1	0	19	29	7	2	0
2	9	7	1	1	6	17	6	1	0	11	30	5	0	0	19	30	6	0	0
2	10	3	1	0	6	18	6	0	0	11	31	4	0	0	19	31	2	2	1
2	11	3	1	0	6	21	9	0	0	12	14	5	0	1	19	32	9	0	1
2	12	6	2	0	6	22	5	1	0	12	17	7	0	1	20	21	4	0	0
2	14	5	2	0	6	23	8	0	0	12	19	3	0	0	20	23	2	1	0
2	16	4	0	1	6	25	4	0	0	12	20	7	1	0	20	24	4	0	0
2	18	3	1	0	6	28	8	2	0	12	27	5	1	0	20	25	4	2	0
2	19	5	0	1	6	29	3	0	0	12	28	6	2	0	20	26	1	0	0
2	24	4	1	1	6	30	1	0	0	12	29	2	0	0	20	29	2	1	1
2	27	8	1	1	6	32	4	0	0	12	32	5	0	1	20	31	2	0	0
2	28	8	0	0	7	9	5	0	0	13	15	2	0	0	20	32	5	0	0
2	29	2	1	0	7	10	7	1	0	13	22	7	1	0	21	22	7	1	1
2	30	5	1	0	7	11	3	2	0	13	25	6	0	0	21	23	3	1	0
3	5	2	0	1	7	12	10	0	1	13	27	6	0	0	21	24	5	0	0
3	8	7	1	2	7	14	2	1	0	13	28	5	0	1	21	27	8	1	1
3	9	5	0	0	7	21	3	0	1	13	31	1	1	0	21	28	7	0	0
3	14	5	0	0	7	22	2	1	0	13	32	6	0	0	22	25	4	0	0
3	16	6	1	0	7	23	5	0	0	14	15	4	0	0	22	26	2	0	0
3	19	5	0	0	7	26	6	0	0	14	16	6	1	0	22	27	5	1	0
3	21	5	1	0	7	27	4	0	0	14	20	4	0	0	22	28	1	0	0
3	24	3	0	0	7	30	2	1	0	14	21	5	0	0	22	29	4	1	0
3	26	7	1	0	8	10	3	0	0	14	27	8	0	1	22	30	6	1	0
3	27	2	0	1	8	12	6	0	0	14	29	5	2	0	22	32	3	0	0
3	28	5	1	0	8	13	1	0	0	14	32	6	2	0	23	24	2	0	1
3	29	6	0	2	8	15	4	0	0	15	16	5	0	0	23	27	5	1	0
3	31	5	0	0	8	16	5	1	0	15	18	2	1	0	23	29	8	0	0
4	5	6	0	0	8	17	5	0	0	15	20	2	1	0	23	30	5	0	0
4	6	5	0	0	8	18	1	1	0	15	21	7	0	0	23	31	6	1	0
4	7	2	0	0	8	23	6	1	0	15	22	6	2	0	23	32	3	0	0
4	8	8	1	0	8	24	3	0	0	15	23	9	0	1	24	29	4	1	0
4	10	4	0	1	8	25	5	1	0	15	24	4	1	0	24	30	4	0	0
4	12	4	0	0	8	29	2	0	0	15	25	5	3	0	24	31	1	1	0
4	13	3	3	0	8	31	5	0	0	15	27	2	0	1	25	26	5	0	0
4	14	5	1	0	8	32	6	0	0	15	31	4	1	0	25	29	8	1	0
4	22	7	0	1	9	12	3	0	1	16	17	9	0	0	25	31	8	0	1
4	23	5	0	0	9	16	1	0	0	16	18	1	1	0	26	28	3	0	0

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Table C.4 – *Continued from previous page*

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
4	24	4	1	0	9	17	9	0	0	16	20	4	1	0	26	29	4	0	0
4	25	5	0	0	9	19	4	0	0	16	21	3	0	0	26	30	4	0	0
4	26	2	0	0	9	20	5	0	0	16	23	5	0	0	27	29	6	0	0
4	31	6	1	0	9	23	6	0	0	16	26	5	2	0	27	30	3	1	1
4	32	6	0	0	9	24	6	2	1	16	28	1	1	0	27	31	4	0	0
5	7	2	0	0	9	25	7	0	0	16	30	2	0	0	28	29	6	1	0
5	8	5	0	0	9	31	7	1	0	16	31	6	0	0	28	32	4	0	0
5	9	7	0	0	10	11	3	0	1	16	32	2	1	1	29	31	6	0	0

Table C.5: GEANT 2 - Case 5

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	2	2	3	0	4	23	3	3	1	10	21	2	3	0	16	30	4	2	0
1	3	3	2	0	4	24	5	3	0	10	26	3	1	0	16	31	2	3	0
1	4	4	3	2	4	26	2	0	0	10	29	5	0	0	16	32	5	1	0
1	5	0	3	1	4	28	0	1	0	10	32	1	3	2	17	19	1	0	0
1	6	0	0	0	4	32	1	0	0	11	12	3	1	0	17	20	2	1	0
1	7	4	1	0	5	8	2	0	0	11	13	4	0	0	17	21	5	1	0
1	8	3	2	0	5	9	2	1	0	11	16	1	0	0	17	23	5	0	1
1	9	6	0	0	5	13	2	2	0	11	17	0	2	0	17	24	4	0	0
1	10	4	0	0	5	14	1	0	0	11	18	4	0	0	17	25	1	0	0
1	11	3	2	0	5	19	4	1	0	11	20	4	0	0	17	32	3	1	0
1	12	3	0	0	5	20	3	0	0	11	21	4	1	0	18	20	6	1	1
1	13	2	2	0	5	22	1	1	0	11	22	5	2	0	18	22	1	0	0
1	14	4	2	1	5	24	5	3	1	11	23	1	0	1	18	24	0	1	0
1	17	2	1	0	5	25	1	1	0	11	25	2	2	1	18	26	3	1	1
1	18	2	1	0	5	30	2	1	0	11	27	2	3	0	18	27	2	2	1
1	19	3	1	1	5	31	0	1	0	11	28	5	1	0	18	30	4	2	1
1	20	1	0	0	5	32	1	3	0	11	29	2	1	0	18	32	2	0	0
1	21	4	1	1	6	8	2	0	0	11	31	2	1	0	19	20	0	1	0
1	24	1	0	0	6	9	6	2	0	12	14	8	2	0	19	22	0	2	1
1	25	3	0	0	6	11	1	1	0	12	16	0	0	0	19	24	4	1	0
1	28	4	1	0	6	12	3	0	0	12	17	2	3	0	19	25	2	2	0
1	30	1	2	0	6	17	2	0	0	12	18	3	1	0	19	26	1	0	0
2	3	2	1	0	6	19	3	3	0	12	19	2	0	0	19	27	3	3	0
2	4	1	0	0	6	22	1	0	0	12	20	3	1	0	19	29	2	0	0
2	7	2	0	0	6	26	2	0	0	12	21	2	1	0	19	31	1	0	1
2	9	2	1	1	6	28	3	0	0	12	22	1	1	1	19	32	1	2	1
2	12	5	1	1	6	29	1	0	0	12	24	1	0	0	20	22	3	0	0
2	13	3	0	0	7	12	1	1	0	12	25	3	1	0	20	23	0	1	0
2	14	2	2	0	7	17	1	2	0	12	29	1	1	0	20	24	1	2	1
2	16	2	1	0	7	18	0	0	0	12	31	2	1	0	20	25	2	0	0
2	17	3	0	1	7	21	1	1	0	13	14	1	1	1	20	26	0	1	0
2	19	0	1	0	7	22	1	2	0	13	15	5	0	0	20	29	2	0	0
2	21	2	2	0	7	24	1	1	1	13	16	2	2	0	20	30	1	3	0
2	22	3	5	0	7	25	6	3	0	13	17	5	1	0	21	25	7	2	0
2	23	5	1	0	7	26	3	1	0	13	19	1	1	0	21	27	3	0	0
2	24	4	2	0	7	27	1	2	0	13	20	2	0	1	21	29	2	2	0
2	25	3	2	0	7	28	2	4	0	13	22	1	0	0	21	30	1	2	1
2	26	1	1	0	7	29	4	4	0	13	25	0	0	0	21	32	0	1	0
2	27	6	0	0	7	31	3	1	0	13	27	3	1	0	22	23	2	2	0
2	28	2	3	0	8	10	3	1	0	14	15	2	1	0	22	26	3	1	0

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Table C.5 – *Continued from previous page*

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
3	4	5	0	0	8	13	2	3	0	14	16	3	2	1	22	27	1	5	0
3	6	4	0	0	8	15	1	2	0	14	19	3	1	0	22	31	3	1	0
3	8	3	1	0	8	16	4	1	0	14	22	1	1	0	23	24	1	2	0
3	9	3	3	0	8	17	4	1	1	14	23	1	1	0	23	25	4	1	1
3	12	1	0	0	8	22	0	2	0	14	24	3	1	0	23	26	1	0	0
3	14	2	1	1	8	30	2	1	0	14	27	3	0	1	23	29	1	1	0
3	15	1	1	1	8	32	2	1	0	14	29	4	1	0	24	25	3	3	0
3	16	2	1	0	9	11	2	0	0	14	32	3	1	0	24	26	3	1	0
3	20	1	2	0	9	12	3	1	0	15	16	3	2	0	24	27	2	0	0
3	23	4	0	0	9	14	2	3	0	15	17	1	5	0	24	30	3	0	0
3	26	2	1	0	9	19	0	0	0	15	20	2	1	0	24	31	2	0	0
3	28	2	0	0	9	20	4	0	1	15	22	2	4	1	24	32	0	1	0
3	29	2	3	0	9	25	3	0	0	15	25	2	1	0	25	26	1	2	0
3	31	3	1	0	9	26	3	1	0	15	29	3	0	0	25	30	1	3	2
3	32	3	0	0	9	27	3	1	0	15	30	2	1	0	25	32	1	1	1
4	6	3	1	0	9	30	2	1	0	15	32	1	0	0	26	27	4	3	0
4	8	3	3	0	10	11	1	2	0	16	19	3	1	0	26	29	1	0	0
4	9	3	1	0	10	12	0	1	2	16	20	1	0	0	27	28	3	1	0
4	13	1	1	0	10	14	2	1	0	16	21	2	1	0	27	30	3	0	0
4	15	2	1	0	10	15	4	2	0	16	23	0	3	0	28	30	2	1	0
4	18	0	0	0	10	17	1	0	0	16	27	1	1	0	28	31	2	1	0
4	20	3	3	0	10	20	2	0	0	16	29	3	0	1	31	32	2	1	0

Table C.6: GEANT 2 - Case 6

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	2	4	2	0	5	6	1	1	0	9	27	2	0	0	16	26	1	1	0
1	3	2	2	1	5	8	1	1	1	9	28	4	2	0	16	27	3	1	0
1	4	3	1	1	5	12	1	3	1	9	31	1	2	0	16	31	4	3	0
1	7	3	1	1	5	13	1	5	0	9	32	2	0	0	17	18	2	1	0
1	8	1	0	1	5	14	2	1	0	10	11	1	1	0	17	20	1	2	0
1	12	0	0	0	5	17	2	3	0	10	12	1	4	0	17	21	2	2	1
1	13	3	3	0	5	18	2	0	1	10	13	0	1	0	17	22	1	0	1
1	14	4	1	1	5	20	3	1	1	10	15	4	1	0	17	23	4	0	0
1	17	1	1	0	5	21	1	0	1	10	16	4	1	0	17	24	2	4	0
1	19	4	1	0	5	23	3	1	0	10	18	3	0	1	17	25	3	2	1
1	21	1	0	1	5	24	1	0	0	10	19	1	2	0	17	29	0	3	0
1	22	2	1	0	5	27	0	1	0	10	20	1	1	0	17	30	3	0	0
1	24	3	2	0	5	30	0	0	1	10	24	2	0	0	18	21	1	1	1
1	25	5	0	1	5	32	2	0	1	10	26	2	0	1	18	25	2	2	0
1	26	3	2	0	6	8	2	2	1	10	27	2	2	0	18	27	3	1	0
1	31	0	1	1	6	10	3	2	0	10	29	5	1	0	18	29	1	1	0
2	3	1	1	0	6	11	0	2	0	10	30	2	0	0	18	30	3	0	0
2	6	0	2	0	6	13	1	1	1	10	31	3	0	0	19	20	0	0	1
2	7	3	1	0	6	14	0	0	0	11	15	1	1	0	19	22	2	1	0
2	8	2	2	0	6	15	0	1	0	11	18	2	0	1	19	23	1	2	1
2	12	0	0	0	6	18	2	0	0	11	21	1	3	1	19	24	2	3	0
2	15	0	2	1	6	20	0	1	0	11	22	4	0	1	19	25	1	1	0
2	16	2	3	0	6	21	2	1	1	11	24	1	2	0	19	27	1	1	0
2	17	4	0	0	6	23	1	2	0	11	26	2	1	0	19	28	2	1	0
2	19	2	1	0	6	25	1	1	0	11	27	4	0	0	19	31	1	0	0
2	21	2	1	0	6	27	2	1	0	11	28	0	1	1	19	32	2	3	0

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Table C.6 – *Continued from previous page*

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
2	23	2	2	0	6	29	1	0	0	11	31	1	2	1	20	22	1	1	0
2	24	3	1	0	6	31	4	0	0	11	32	2	1	0	20	23	1	1	0
2	28	0	0	0	7	8	2	2	0	12	13	3	1	0	20	24	2	1	0
2	29	1	0	0	7	10	1	0	1	12	14	2	2	0	20	26	2	0	0
2	32	0	0	0	7	11	2	1	0	12	19	3	2	0	20	27	1	0	0
3	4	3	4	0	7	17	2	0	0	12	20	1	1	0	20	28	2	1	0
3	5	4	0	2	7	18	1	1	0	12	21	1	1	0	20	31	1	2	0
3	7	2	1	0	7	21	2	2	0	12	22	1	3	1	21	22	4	0	0
3	8	2	1	0	7	22	3	0	1	12	24	0	0	0	21	23	1	0	1
3	9	1	2	0	7	27	2	1	3	12	26	0	4	0	21	25	2	0	1
3	11	3	0	0	7	28	2	1	0	13	14	1	1	0	21	26	3	1	1
3	12	5	2	0	7	30	4	2	0	13	18	3	2	0	21	28	2	2	0
3	13	1	0	0	7	31	3	1	0	13	19	4	3	0	21	29	3	1	1
3	18	3	3	1	8	12	1	1	0	13	20	0	0	0	21	30	2	3	1
3	19	1	2	1	8	13	1	1	0	13	21	2	0	0	21	31	4	2	1
3	21	0	1	0	8	15	3	0	0	13	23	2	1	0	22	24	2	1	1
3	24	1	3	0	8	17	5	0	0	13	32	2	3	0	22	26	2	3	2
3	25	2	1	1	8	18	1	1	0	14	15	0	0	0	22	27	1	2	0
3	27	1	0	0	8	22	0	1	0	14	17	3	1	0	22	28	0	4	0
3	28	0	0	0	8	23	1	2	1	14	18	3	2	0	22	29	3	1	0
3	30	0	0	0	8	24	1	2	0	14	19	2	1	0	23	24	0	1	1
3	31	2	2	0	8	25	0	2	0	14	20	3	4	0	23	26	1	0	0
3	32	1	0	1	8	26	3	2	0	14	25	2	0	1	23	28	3	1	0
4	5	2	0	0	8	31	2	1	0	14	28	3	0	0	23	32	6	1	1
4	8	1	1	0	8	32	3	1	1	14	30	3	1	0	24	26	3	1	1
4	9	5	3	1	9	10	0	2	0	15	18	0	1	0	24	27	2	2	1
4	11	1	0	1	9	11	2	2	0	15	21	5	2	0	24	31	3	1	0
4	13	3	0	0	9	12	1	0	2	15	22	1	0	0	25	26	0	2	1
4	14	1	1	0	9	14	0	0	0	15	23	1	0	0	25	30	1	0	1
4	15	2	1	1	9	15	0	1	0	15	26	1	2	1	25	31	1	1	0
4	17	2	2	1	9	17	2	1	2	15	27	0	2	0	26	27	1	0	0
4	21	1	2	1	9	20	2	2	1	15	29	0	0	0	27	30	3	0	0
4	23	1	0	0	9	22	3	1	1	15	32	1	1	0	28	30	2	2	0
4	25	1	3	0	9	23	3	0	0	16	17	2	1	2	28	31	3	1	0
4	26	2	0	1	9	24	2	0	0	16	18	1	0	0	29	32	0	1	0
4	28	8	2	1	9	25	3	3	0	16	20	3	1	0	30	31	2	1	0

Table C.7: GEANT 2 - Case 7

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	2	4	3	1	5	21	3	0	1	10	22	3	0	0	16	30	1	2	0
1	3	2	3	0	5	22	1	0	0	10	23	6	1	1	16	31	5	0	0
1	6	5	0	0	5	23	9	1	0	10	24	4	0	1	16	32	4	0	0
1	7	2	0	1	5	24	4	1	0	10	27	8	2	0	17	18	3	0	0
1	8	4	1	0	5	25	2	0	0	10	29	3	0	0	17	20	2	1	0
1	9	4	0	0	5	26	5	2	0	10	30	4	0	0	17	22	4	0	0
1	12	6	0	0	5	27	7	1	0	11	12	2	1	0	17	23	4	0	0
1	13	3	0	0	5	28	5	1	0	11	13	5	1	0	17	24	2	1	0
1	14	4	1	0	5	31	1	0	0	11	17	5	0	1	17	25	4	0	0
1	15	4	0	0	5	32	4	0	0	11	18	8	0	1	17	27	3	0	0
1	17	1	0	0	6	7	5	0	1	11	19	1	0	0	17	28	7	1	0
1	18	3	0	0	6	8	3	0	1	11	20	3	1	1	17	29	4	0	0

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Table C.7 – *Continued from previous page*

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	19	3	1	0	6	9	3	2	0	11	21	5	0	1	17	31	4	1	0
1	22	3	1	3	6	11	3	2	0	11	22	10	1	0	17	32	3	1	0
1	24	6	2	0	6	12	4	1	0	11	23	3	0	0	18	19	2	0	0
1	25	5	0	0	6	13	3	1	0	11	24	4	0	0	18	20	2	0	0
1	27	5	0	0	6	14	8	1	0	11	25	2	1	0	18	21	4	0	0
1	28	3	1	0	6	15	3	1	0	11	26	3	0	0	18	22	3	0	0
1	29	8	1	1	6	16	2	0	0	11	27	4	0	0	18	24	3	1	0
2	7	4	1	1	6	17	2	1	1	11	29	3	0	0	18	25	6	0	0
2	8	4	0	1	6	19	4	0	0	11	30	2	0	1	18	26	7	0	0
2	9	3	0	0	6	21	3	0	0	11	32	1	1	0	18	28	5	0	1
2	11	4	1	0	6	22	3	1	0	12	13	2	0	0	18	29	3	2	0
2	16	2	0	0	6	24	6	0	0	12	14	9	0	0	18	31	6	0	0
2	19	5	0	0	6	27	2	1	1	12	18	3	1	0	18	32	4	0	0
2	20	3	1	0	6	29	3	0	0	12	19	2	0	0	19	20	4	0	0
2	21	2	2	0	6	30	5	0	0	12	20	2	0	0	19	21	2	0	0
2	23	5	1	0	6	31	0	0	1	12	22	5	0	0	19	22	3	0	0
2	24	7	0	0	7	8	4	0	0	12	24	4	0	0	19	23	6	0	1
2	25	9	0	0	7	11	4	0	0	12	25	3	0	1	19	26	3	1	0
2	27	6	0	0	7	12	4	1	0	12	26	4	0	1	19	27	4	0	0
2	29	2	1	0	7	14	2	2	0	12	27	3	0	0	19	29	3	0	0
2	32	2	1	1	7	15	4	1	0	12	31	6	2	0	19	30	3	1	0
3	4	1	0	0	7	16	5	0	0	12	32	4	1	0	20	21	4	0	0
3	6	4	0	0	7	17	3	0	0	13	14	3	1	0	20	22	4	0	0
3	7	1	1	0	7	18	5	1	0	13	15	1	0	1	20	23	5	1	0
3	8	3	0	0	7	19	1	1	0	13	16	6	0	1	20	25	2	0	0
3	10	7	2	0	7	20	1	1	0	13	17	6	0	1	20	26	6	1	0
3	12	4	0	0	7	21	8	0	0	13	18	5	0	0	20	28	4	0	1
3	13	4	1	0	7	22	4	0	0	13	19	3	0	0	20	29	5	0	0
3	14	3	0	0	7	26	6	0	0	13	22	5	0	1	20	30	5	0	0
3	16	3	0	0	7	27	4	0	0	13	23	3	0	0	21	22	6	0	0
3	17	2	1	0	7	28	3	1	0	13	24	7	1	1	21	24	5	0	0
3	18	4	1	0	7	30	3	0	0	13	25	6	0	0	21	26	3	0	0
3	19	5	0	0	7	32	3	0	0	13	26	3	0	0	21	27	8	1	0
3	20	5	0	0	8	10	4	0	0	13	27	5	0	0	21	29	1	0	0
3	22	6	2	0	8	11	5	0	0	13	29	4	0	0	21	30	2	0	1
3	24	1	0	0	8	12	4	0	1	13	31	6	0	0	21	31	4	0	0
3	25	7	0	1	8	15	4	0	0	13	32	5	0	0	21	32	2	1	0
3	28	3	0	0	8	16	3	1	0	14	15	7	1	0	22	23	8	0	0
3	30	2	1	0	8	17	3	0	0	14	17	3	0	0	22	24	4	2	0
3	31	7	0	0	8	18	5	0	0	14	18	4	0	1	22	26	2	0	0
3	32	1	0	0	8	19	4	0	0	14	19	5	0	0	22	27	3	1	0
4	5	3	0	0	8	20	4	2	0	14	20	6	0	0	22	28	2	0	0
4	6	3	0	0	8	22	2	1	0	14	21	4	1	0	22	29	4	0	0
4	7	8	0	0	8	24	3	0	0	14	22	2	1	0	22	31	5	1	0
4	8	1	0	0	8	25	4	1	0	14	24	2	1	0	23	25	5	1	0
4	9	2	0	0	8	26	1	0	0	14	25	4	0	0	23	26	3	0	0
4	10	0	0	0	8	27	4	1	0	14	26	3	1	0	23	27	3	0	0
4	11	6	0	0	8	28	3	1	1	14	27	8	0	1	23	28	4	0	0
4	13	7	1	0	8	29	7	0	0	14	28	7	2	0	23	29	3	2	0
4	14	2	0	0	8	31	8	1	0	14	29	6	0	0	24	25	2	0	0
4	15	2	1	0	9	11	5	0	0	14	31	7	1	0	24	26	1	0	0
4	17	5	0	0	9	12	8	0	0	14	32	5	1	0	24	27	4	0	0
4	18	5	1	0	9	13	8	1	0	15	16	5	0	1	24	29	4	1	1
4	19	1	1	0	9	16	6	0	0	15	17	4	0	0	24	32	6	2	0
4	21	6	0	0	9	17	8	0	0	15	20	5	1	0	25	28	3	0	0

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Table C.7 – *Continued from previous page*

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
4	22	6	1	0	9	18	3	1	0	15	22	2	1	0	25	30	8	1	0
4	23	8	1	0	9	19	9	0	0	15	23	3	1	0	26	27	6	1	0
4	25	3	0	1	9	21	4	1	0	15	26	2	1	0	26	28	2	2	0
4	30	2	0	0	9	25	2	1	0	15	27	5	2	1	26	31	8	1	1
4	31	2	2	0	9	27	3	0	0	15	29	5	1	0	26	32	1	1	0
5	6	2	1	0	9	28	3	1	0	15	31	3	0	0	27	29	5	0	0
5	9	4	0	0	9	29	5	0	1	15	32	6	0	0	27	30	4	1	1
5	10	4	0	0	9	31	2	0	0	16	17	3	1	0	27	31	4	0	0
5	11	4	0	0	9	32	2	1	0	16	18	4	1	0	27	32	6	0	1
5	13	2	0	0	10	12	7	1	0	16	19	4	0	0	28	31	3	0	0
5	14	3	1	0	10	14	1	0	0	16	20	4	2	0	28	32	7	1	0
5	16	4	0	0	10	15	4	1	0	16	21	4	0	1	29	31	8	1	0
5	17	6	1	0	10	16	6	1	0	16	22	1	0	1	29	32	8	1	0
5	18	6	0	0	10	19	4	0	0	16	27	4	0	1	31	32	4	1	0
5	19	2	0	0	10	20	4	0	0	16	28	2	0	1					
5	20	3	0	0	10	21	1	0	0	16	29	3	1	0					

Table C.8: GEANT 2 - Case 8

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	3	2	2	1	5	25	0	3	0	10	29	3	0	1	17	29	1	1	0
1	5	1	1	0	5	26	3	0	0	10	30	1	3	0	17	30	0	2	0
1	9	2	0	0	5	27	0	2	0	10	31	1	1	1	17	31	2	0	0
1	10	4	0	0	5	29	5	2	0	10	32	0	0	0	17	32	2	0	0
1	11	2	0	0	5	30	3	0	0	11	12	1	0	0	18	20	4	0	0
1	12	0	0	0	6	9	1	1	0	11	15	3	1	0	18	21	3	0	0
1	13	0	0	0	6	10	1	2	0	11	17	2	3	0	18	22	1	1	0
1	14	3	0	0	6	12	0	0	0	11	21	3	2	0	18	23	2	1	0
1	15	1	2	0	6	13	1	1	0	11	23	4	0	1	18	27	3	1	1
1	18	1	2	0	6	15	2	1	0	11	24	0	1	0	18	28	5	1	0
1	19	1	1	0	6	16	2	2	0	11	25	4	0	1	18	30	2	0	0
1	20	2	2	0	6	17	2	0	0	11	26	2	1	1	18	32	2	1	0
1	21	1	1	0	6	20	2	2	0	11	28	4	2	0	19	20	4	1	0
1	22	4	2	0	6	21	3	1	1	11	29	0	2	0	19	21	1	1	0
1	25	1	2	0	6	23	3	1	0	12	14	0	0	0	19	23	0	1	1
1	27	1	3	1	6	24	3	0	0	12	15	3	0	0	19	25	0	2	0
1	28	3	2	0	6	27	3	1	0	12	17	1	2	0	19	26	3	0	0
1	30	1	2	0	6	28	1	2	0	12	18	1	0	0	19	28	1	2	0
2	3	2	3	0	6	32	5	0	0	12	19	2	3	0	19	29	2	1	0
2	4	3	0	0	7	9	2	3	1	12	21	2	1	0	19	31	3	1	0
2	6	1	0	0	7	10	6	0	0	12	23	2	0	0	19	32	2	1	0
2	7	2	2	0	7	13	2	1	0	12	24	2	3	1	20	22	3	0	1
2	9	1	0	1	7	14	1	0	0	12	25	2	0	1	20	23	0	1	1
2	12	3	0	1	7	15	3	2	0	12	28	3	1	1	20	24	2	0	0
2	13	1	2	0	7	16	2	2	0	12	30	1	1	0	20	25	1	0	0
2	14	2	0	0	7	17	1	0	0	12	32	5	0	0	20	26	0	0	1
2	15	3	2	0	7	18	1	2	0	13	14	1	2	0	20	27	2	2	1
2	17	6	0	0	7	19	1	0	0	13	15	2	1	0	20	28	1	2	0
2	19	2	0	0	7	20	3	1	0	13	16	1	3	0	20	29	0	0	0
2	21	2	2	0	7	25	0	0	1	13	17	2	2	1	20	31	3	1	0
2	23	1	0	0	7	26	0	0	0	13	18	4	3	0	20	32	4	1	0
2	26	3	2	0	7	28	4	1	0	13	19	0	1	0	21	24	1	0	1

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Table C.8 – *Continued from previous page*

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
2	29	2	0	0	7	30	1	1	0	13	20	1	0	0	21	25	2	2	0
2	32	1	2	1	7	31	1	2	0	13	22	2	2	0	21	26	0	1	0
3	4	2	0	0	7	32	1	0	0	13	23	1	1	0	21	27	7	1	0
3	5	3	0	0	8	9	3	0	0	13	24	4	1	0	21	28	1	1	0
3	6	5	2	0	8	10	5	0	0	13	25	3	0	1	21	30	0	1	0
3	8	0	0	0	8	11	2	2	0	13	26	1	0	0	21	32	3	0	0
3	9	5	1	0	8	12	4	2	1	13	27	2	0	0	22	23	0	4	1
3	11	2	0	0	8	13	4	0	0	13	29	0	0	1	22	24	2	2	0
3	12	2	3	0	8	14	2	0	0	13	30	1	2	0	22	25	3	1	0
3	13	3	1	0	8	15	1	0	0	13	31	1	0	0	22	26	0	1	1
3	14	3	3	0	8	16	8	1	0	14	15	6	0	0	22	27	3	0	0
3	16	1	1	1	8	17	1	0	0	14	17	4	0	0	22	28	0	1	0
3	17	3	1	0	8	18	2	0	0	14	19	1	1	0	22	29	1	1	0
3	18	2	1	0	8	19	2	0	0	14	22	4	0	0	22	31	1	0	0
3	20	2	0	0	8	21	3	0	0	14	23	4	0	0	22	32	1	1	0
3	21	2	0	0	8	22	2	0	0	14	24	2	2	0	23	24	2	3	1
3	24	1	1	0	8	23	1	4	0	14	26	1	2	1	23	25	2	2	0
3	25	0	2	0	8	24	2	1	0	14	27	1	0	0	23	26	1	3	0
3	26	2	0	0	8	25	1	0	0	14	28	0	1	0	23	27	2	1	1
3	27	3	1	0	8	26	2	0	0	14	30	3	0	1	23	29	2	3	0
3	28	2	3	0	8	27	2	1	0	14	32	2	1	1	23	30	3	0	0
3	29	2	2	0	8	29	2	2	0	15	16	4	3	0	23	31	1	2	0
3	30	0	0	1	8	30	0	2	0	15	17	3	1	0	23	32	2	0	1
3	31	0	3	0	8	32	3	0	0	15	18	2	0	0	24	25	0	1	0
4	7	3	1	0	9	10	3	2	0	15	20	3	2	0	24	26	1	2	0
4	9	1	1	0	9	11	3	0	0	15	22	4	1	0	24	27	2	2	0
4	11	3	1	0	9	12	0	0	1	15	24	2	1	0	24	28	4	1	0
4	14	2	2	0	9	13	1	1	0	15	25	2	0	0	24	29	1	0	0
4	15	1	1	0	9	15	2	4	0	15	26	3	0	0	24	30	0	1	0
4	20	1	2	0	9	16	2	1	0	15	27	3	0	0	24	31	2	0	0
4	22	2	0	0	9	17	3	0	0	15	29	1	0	0	25	26	1	2	1
4	23	3	1	0	9	18	3	0	0	15	30	3	1	0	25	27	0	0	0
4	25	0	0	1	9	21	0	0	0	15	31	5	0	0	25	29	1	0	0
4	26	4	1	0	9	22	1	0	0	16	18	1	1	0	25	32	1	2	0
4	27	1	0	1	9	23	0	0	0	16	19	1	0	0	26	27	1	1	0
4	28	0	1	0	9	24	0	1	0	16	20	1	1	0	26	28	1	0	0
4	29	3	2	1	9	25	2	0	0	16	23	3	0	0	26	29	3	2	0
4	30	3	0	0	9	26	3	1	1	16	24	1	0	0	26	30	1	1	1
4	32	5	2	0	9	27	3	2	0	16	25	3	2	0	26	31	5	0	0
5	7	4	2	0	9	30	0	0	0	16	29	2	1	0	26	32	2	1	0
5	8	6	0	0	9	32	1	3	0	16	30	1	2	0	27	28	2	3	1
5	9	3	0	0	10	12	2	4	0	16	31	1	0	0	27	29	3	0	0
5	11	4	1	0	10	15	1	4	0	16	32	1	1	0	27	30	1	0	0
5	14	3	1	0	10	16	1	1	0	17	18	2	0	0	28	31	1	0	0
5	16	1	1	0	10	18	3	1	0	17	20	3	3	0	28	32	3	2	0
5	17	1	2	0	10	19	2	1	0	17	21	3	2	0	29	30	1	1	1
5	18	0	2	0	10	20	3	0	1	17	22	2	1	0	29	32	3	1	1
5	19	1	1	0	10	24	2	1	0	17	24	2	1	1	30	31	3	0	0
5	20	0	2	0	10	25	1	1	0	17	25	1	1	0	31	32	3	2	0
5	22	4	2	0	10	27	3	1	1	17	26	2	0	0					
5	24	8	0	0	10	28	1	2	0	17	28	2	1	0					

Table C.9: GEANT 2 - Case 9

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	2	2	0	0	5	25	1	0	0	10	22	0	2	0	16	29	2	0	0
1	4	0	0	0	5	27	2	1	0	10	23	2	0	0	16	30	0	3	0
1	5	1	1	0	5	28	1	2	0	10	26	1	0	1	16	32	1	1	0
1	7	0	1	1	5	29	5	0	0	10	27	2	0	0	17	18	1	2	0
1	8	0	1	0	5	31	3	2	0	10	28	1	1	0	17	19	3	2	1
1	9	3	0	1	5	32	2	0	1	10	30	3	0	0	17	20	3	2	1
1	10	1	1	0	6	7	2	0	0	10	31	2	1	0	17	21	1	0	0
1	11	1	0	1	6	8	0	1	1	11	12	3	2	0	17	22	0	1	0
1	12	0	3	0	6	9	0	0	0	11	13	1	0	2	17	26	4	2	0
1	13	2	0	1	6	10	1	0	0	11	16	4	3	0	17	27	1	2	2
1	14	4	0	0	6	11	1	0	0	11	18	2	1	2	17	28	1	0	0
1	15	2	0	0	6	12	1	1	0	11	19	2	0	0	17	30	2	2	0
1	17	1	2	0	6	13	2	2	0	11	20	1	2	0	17	32	0	0	0
1	20	0	0	1	6	14	1	1	0	11	21	2	0	0	18	21	2	1	0
1	21	4	1	1	6	16	3	3	1	11	24	4	1	0	18	23	0	3	0
1	22	0	2	0	6	17	0	4	0	11	25	1	1	0	18	24	3	0	2
1	23	1	1	0	6	19	3	0	0	11	26	1	1	1	18	25	2	0	1
1	26	2	2	0	6	20	0	0	0	11	27	0	2	0	18	26	1	0	0
1	28	1	1	0	6	21	1	1	1	11	28	1	3	0	18	27	1	1	0
1	29	3	2	0	6	22	1	0	0	11	29	1	1	0	18	29	0	1	1
1	30	2	2	0	6	23	1	1	0	12	13	1	0	0	18	30	5	1	0
1	31	0	1	0	6	24	1	5	0	12	14	0	0	0	19	21	2	1	0
1	32	2	0	1	6	25	3	0	0	12	15	0	1	0	19	22	1	1	0
2	3	1	1	0	6	27	1	0	0	12	16	3	0	1	19	23	3	1	0
2	4	0	2	0	6	29	1	1	0	12	17	3	1	0	19	26	0	0	0
2	7	0	1	0	6	30	1	1	0	12	18	2	0	0	19	27	2	1	0
2	9	1	1	0	6	31	1	3	0	12	19	4	1	2	19	28	1	0	0
2	10	3	0	1	7	8	2	2	0	12	20	3	0	0	19	30	0	0	0
2	12	1	3	1	7	10	0	2	1	12	22	2	0	0	19	32	1	2	0
2	14	2	2	0	7	12	2	0	0	12	23	0	0	0	20	21	4	0	1
2	15	2	3	0	7	14	2	0	0	12	25	2	0	0	20	22	0	0	0
2	16	2	0	0	7	15	1	1	2	12	26	1	3	0	20	23	1	0	0
2	18	1	2	0	7	16	2	1	0	12	27	2	0	1	20	25	1	2	0
2	21	0	3	0	7	17	1	0	2	12	28	0	3	0	20	26	1	0	0
2	22	3	4	0	7	18	0	1	0	12	30	2	1	0	20	27	3	0	0
2	24	3	1	1	7	19	1	2	0	12	31	2	1	0	20	28	3	0	0
2	26	3	3	0	7	20	1	0	0	12	32	3	0	0	20	29	1	0	0
2	27	0	1	0	7	24	1	1	0	13	14	2	0	2	20	32	0	2	0
2	28	1	2	0	7	25	3	2	0	13	15	1	1	0	21	22	1	1	0
2	29	4	1	0	7	27	1	1	0	13	16	2	1	1	21	23	2	0	0
2	32	2	0	0	7	28	0	1	0	13	17	2	0	1	21	24	1	0	0
3	6	0	3	1	7	29	3	0	1	13	18	3	0	1	21	25	2	0	0
3	7	1	2	0	7	30	0	1	0	13	19	0	3	0	21	26	2	0	0
3	11	1	1	0	7	31	1	0	2	13	22	2	1	0	21	27	3	0	2
3	12	2	2	0	8	10	1	1	0	13	24	3	0	0	21	28	1	1	0
3	18	2	0	1	8	12	0	2	0	13	26	1	4	0	21	30	1	1	0
3	19	1	2	0	8	13	3	0	0	13	27	3	0	0	21	31	0	2	0
3	20	0	0	0	8	14	3	3	0	13	30	4	1	0	21	32	0	2	1
3	22	2	0	0	8	15	2	1	0	13	31	2	0	0	22	24	1	0	0
3	26	2	0	0	8	17	0	2	0	13	32	2	4	0	22	26	3	2	0
3	28	2	3	0	8	18	1	1	0	14	15	1	2	0	22	28	1	0	0
3	29	2	0	0	8	19	3	0	0	14	16	1	0	0	23	24	0	0	1
3	30	0	0	0	8	23	0	0	2	14	17	3	1	2	23	25	1	2	0
3	31	1	3	0	8	24	0	2	1	14	18	3	1	0	23	27	2	0	0

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Table C.9 – *Continued from previous page*

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
3	32	1	1	0	8	25	4	0	0	14	20	2	1	0	23	28	1	1	0
4	5	4	1	0	8	27	0	2	0	14	22	3	1	0	23	29	1	1	1
4	6	2	1	0	8	29	4	2	0	14	23	1	2	1	23	31	0	1	0
4	8	1	2	0	8	32	4	1	0	14	24	2	0	1	24	25	4	0	0
4	10	4	3	1	9	10	3	2	0	14	25	3	2	1	24	27	2	1	0
4	13	0	2	0	9	11	2	2	0	14	26	3	2	1	24	28	1	2	0
4	14	3	3	1	9	12	2	0	0	14	29	2	2	0	24	29	2	0	0
4	15	0	1	0	9	13	2	0	0	14	30	0	0	0	24	30	2	0	2
4	16	5	0	0	9	14	3	2	0	14	32	0	1	1	24	31	3	1	0
4	17	4	0	0	9	15	1	1	0	15	16	5	2	0	25	27	1	0	1
4	18	1	2	0	9	17	2	1	0	15	18	3	0	0	25	28	1	1	0
4	19	4	0	0	9	18	2	0	0	15	20	1	1	0	25	29	1	1	0
4	20	0	0	0	9	19	1	2	1	15	21	1	1	1	26	29	1	2	0
4	21	2	2	0	9	21	1	1	1	15	22	0	3	0	26	32	1	0	0
4	22	3	1	0	9	22	2	1	0	15	23	2	0	0	27	29	1	0	0
4	23	1	1	0	9	23	3	1	0	15	24	2	0	0	27	30	0	1	0
4	24	0	2	0	9	24	0	1	0	15	25	0	1	0	27	31	1	0	0
4	27	1	1	2	9	25	0	2	0	15	26	2	0	1	27	32	0	1	1
4	28	1	0	0	9	26	4	0	0	15	27	3	3	0	28	29	2	0	0
4	29	2	2	0	9	27	1	0	0	15	28	0	1	1	28	30	1	0	0
4	30	2	0	1	9	30	0	0	1	15	29	3	1	1	28	31	2	0	0
4	31	2	2	1	10	12	3	0	0	15	30	2	0	0	28	32	5	1	1
4	32	2	0	0	10	13	2	1	0	15	31	1	4	0	29	30	0	0	1
5	8	2	1	0	10	14	2	2	0	15	32	4	0	0	29	31	4	2	2
5	15	1	1	1	10	16	6	0	0	16	17	1	3	0	29	32	1	0	0
5	16	2	1	0	10	17	0	0	0	16	19	2	2	0	30	31	0	1	1
5	17	2	1	1	10	19	3	0	0	16	20	0	2	1	31	32	1	2	0
5	20	1	0	0	10	20	2	0	0	16	21	1	2	1					
5	24	0	1	1	10	21	2	0	0	16	27	0	1	0					

C.2 EON

Table C.10: EON - Case 1

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	3	11	0	0	3	19	13	1	1	6	14	23	0	1	11	19	17	1	2
1	4	16	2	1	4	5	19	2	1	6	18	20	3	3	12	13	18	2	0
1	5	17	4	1	4	8	11	1	3	7	10	11	0	0	12	14	10	5	1
1	11	18	1	1	4	11	18	4	0	7	11	17	3	1	12	15	14	1	0
1	13	19	1	1	4	13	19	5	0	7	13	18	0	0	12	16	14	1	0
1	15	21	4	0	4	18	13	5	1	7	16	20	6	0	12	17	14	2	2
1	16	26	3	0	4	19	15	0	0	7	19	22	1	1	12	19	16	2	0
2	3	21	4	2	5	6	21	5	0	8	9	20	3	0	14	17	14	2	1
2	5	17	1	0	5	7	17	1	0	8	15	26	2	1	16	19	18	3	1
2	8	16	0	0	5	8	24	1	1	8	17	17	1	1	17	18	12	2	0
2	16	29	4	0	5	14	21	2	0	9	12	13	3	1	17	19	9	4	0
2	19	16	2	1	5	15	16	0	1	9	14	22	2	3	18	19	22	1	1
3	4	18	0	0	5	17	19	3	1	10	12	20	2	1					
3	6	19	4	0	5	18	11	3	1	10	18	19	2	0					
3	9	16	1	0	6	9	16	1	0	11	14	21	1	2					

Table C.11: EON - Case 2

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	4	12	2	0	2	16	10	1	1	6	15	14	5	0	10	13	6	6	2
1	5	7	3	0	2	17	5	4	1	7	8	11	4	1	10	16	6	5	0
1	7	6	6	3	2	19	5	3	1	7	9	9	4	0	10	19	13	10	0
1	9	10	1	3	3	6	10	5	2	7	11	14	5	1	11	14	10	5	1
1	12	7	1	0	3	14	6	6	1	7	12	8	6	3	11	15	5	2	1
1	17	9	4	0	3	16	7	4	0	7	14	7	7	1	12	13	5	5	2
1	19	10	1	3	4	5	9	2	0	8	10	7	3	0	13	19	14	5	0
2	3	7	4	0	4	9	14	9	0	8	15	5	3	1	14	15	3	2	0
2	4	9	5	0	4	16	8	5	1	9	10	9	3	0	15	16	10	5	0
2	8	7	4	0	4	19	18	3	0	9	11	7	5	1	15	17	12	7	1
2	9	13	1	0	5	10	14	2	4	9	13	10	1	0	15	19	8	4	1
2	10	10	5	1	5	11	5	3	3	9	16	11	2	0	16	17	7	8	0
2	11	8	4	1	5	12	5	3	0	9	17	4	10	1					
2	12	11	7	3	5	19	11	3	1	9	19	9	7	1					
2	15	7	5	0	6	7	8	3	2	10	11	8	2	1					

Table C.12: EON - Case 3

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	2	8	5	0	4	5	5	6	0	6	8	5	5	3	10	12	8	0	3
1	9	7	4	0	4	7	7	2	1	6	12	6	8	0	10	19	5	3	3
1	19	5	3	1	4	8	8	3	1	6	13	3	4	4	11	14	7	11	0
2	3	5	8	1	4	15	4	0	1	6	15	9	2	1	12	15	12	2	1
2	7	9	4	3	4	17	6	6	1	7	14	8	5	1	12	16	5	10	0
2	10	6	2	1	4	18	3	2	2	7	15	3	4	2	12	18	9	3	3
2	14	5	6	1	4	19	6	6	4	7	16	5	1	2	13	15	8	7	2
2	15	10	5	0	5	6	5	5	1	7	18	7	5	1	14	16	7	3	3
2	18	5	4	2	5	7	7	7	0	8	9	4	6	2	16	17	4	3	1
2	19	3	4	1	5	8	11	4	1	8	19	7	3	2	16	18	5	5	0
3	4	5	1	2	5	9	4	3	0	9	10	5	4	1	17	19	6	5	2
3	7	3	4	0	5	14	7	7	2	9	15	7	3	1	18	19	1	7	1
3	11	5	7	0	5	15	5	8	1	9	18	8	4	3					
3	12	8	3	2	5	17	6	7	0	9	19	6	1	1					
3	14	9	1	6	5	19	10	5	1	10	11	3	4	1					

Table C.13: EON - Case 4

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	2	16	4	0	3	13	12	3	2	6	19	8	2	0	10	19	9	1	0
1	3	10	2	1	3	17	9	0	1	7	8	18	3	0	11	13	17	2	0
1	5	13	2	3	3	19	17	3	0	7	9	12	3	1	11	16	20	1	2
1	14	8	0	1	4	5	16	0	0	7	12	9	0	1	11	17	11	0	0
1	18	17	3	0	4	8	6	2	1	7	14	23	1	1	11	18	23	0	2
2	4	14	2	0	4	9	14	4	2	7	15	14	2	0	11	19	13	4	0
2	5	12	2	0	4	10	16	1	0	7	17	11	0	0	12	13	13	1	0
2	6	13	3	0	4	11	14	2	0	8	12	18	4	0	12	14	22	0	1
2	8	15	3	0	4	13	21	0	1	8	13	16	0	0	12	17	12	2	0
2	9	15	2	1	4	18	13	1	0	8	14	14	6	0	12	19	16	3	1
2	11	13	1	1	4	19	24	2	0	8	15	18	1	0	13	14	14	4	2
2	12	15	1	0	5	6	14	2	2	8	17	18	1	1	13	17	14	2	0
2	14	15	1	1	5	8	13	3	2	9	10	10	2	2	13	18	22	0	2
2	15	12	0	0	5	11	6	3	1	9	11	11	2	2	14	15	7	2	1
2	16	21	3	0	5	12	11	2	0	9	12	12	4	1	14	16	19	4	0
2	17	13	3	0	5	13	11	2	1	9	16	12	1	0	14	19	18	2	0
2	18	14	1	0	5	14	13	0	0	9	17	17	2	1	15	18	17	0	0
3	6	14	2	0	5	18	18	1	0	9	19	16	1	1	15	19	15	2	2
3	8	21	4	1	6	8	19	3	0	10	11	8	0	0	16	18	16	0	0
3	9	14	0	0	6	11	19	1	1	10	13	22	1	0					
3	10	15	3	1	6	14	20	1	1	10	14	11	1	0					
3	12	14	1	0	6	17	16	4	0	10	18	18	0	1					

Table C.14: EON - Case 5

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	2	12	3	0	3	12	11	5	1	6	19	7	3	1	11	17	14	3	1
1	3	4	4	2	3	13	7	3	0	7	8	9	3	0	11	18	9	6	0
1	5	9	5	0	3	16	9	4	0	7	9	7	9	1	12	15	5	6	0
1	8	3	2	0	3	17	12	8	1	7	10	8	5	0	12	16	11	3	1
1	9	5	5	1	3	18	3	1	3	7	11	6	4	1	12	19	13	2	0
1	11	5	4	2	3	19	8	6	1	7	14	5	4	0	13	16	9	3	0
1	18	8	2	1	4	7	6	1	0	7	16	6	4	2	13	17	2	3	1
1	19	14	0	0	4	8	5	2	1	7	17	8	2	0	13	18	3	3	1
2	4	4	2	1	4	10	6	4	0	7	19	2	2	1	14	15	6	3	4
2	6	9	6	2	4	12	4	2	2	8	10	8	5	4	14	16	7	2	0
2	7	6	3	0	4	17	9	6	0	8	11	11	3	2	14	17	12	4	2
2	8	13	5	0	5	6	7	4	0	8	13	10	2	0	14	18	9	2	0
2	15	4	5	1	5	9	5	2	2	8	15	9	5	1	14	19	8	2	1
2	16	11	5	0	5	13	6	4	0	8	17	7	4	1	15	16	8	4	0
2	17	6	5	2	5	14	11	2	0	8	19	3	3	0	15	17	11	4	0
2	19	6	6	0	5	15	7	5	1	9	11	9	3	0	15	18	5	3	1
3	4	6	3	1	5	16	6	7	0	9	14	4	3	4	16	17	11	4	0
3	5	4	2	0	5	17	6	6	1	9	16	4	4	0	17	19	3	0	0
3	6	6	3	0	6	10	5	3	2	9	17	10	4	0	18	19	5	1	0
3	7	6	2	0	6	14	5	0	0	9	19	10	5	0					
3	9	6	5	1	6	15	9	2	0	10	13	7	1	1					
3	10	15	1	0	6	17	7	5	1	10	19	8	4	2					

Table C.15: EON - Case 6

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	3	4	5	2	4	7	3	3	1	7	15	10	6	0	11	16	5	6	1
1	5	3	4	2	4	14	8	4	2	7	17	8	4	2	11	17	5	5	0
1	8	7	3	3	4	17	6	3	4	7	18	5	4	0	11	18	5	1	0
1	9	6	5	0	5	6	9	3	0	7	19	8	4	2	11	19	2	2	2
1	14	6	5	1	5	7	4	5	1	8	10	7	4	1	12	13	2	4	1
1	16	8	3	1	5	9	8	4	2	8	13	6	7	0	12	15	4	3	1
1	18	7	4	3	5	10	4	7	2	8	14	11	3	0	12	16	4	4	0
2	5	4	1	1	5	11	5	2	0	8	15	5	5	2	13	15	6	3	3
2	6	7	6	1	5	15	5	2	4	8	18	9	3	0	13	16	3	1	2
2	11	1	4	1	5	16	9	4	2	8	19	6	5	2	13	17	6	7	1
2	13	6	1	1	5	17	7	6	4	9	10	4	4	2	13	18	8	2	3
2	14	3	4	0	5	18	3	3	1	9	12	6	3	1	14	17	6	3	0
3	5	6	3	2	6	7	4	5	0	9	16	7	2	1	15	16	4	5	1
3	7	4	4	3	6	10	6	2	0	9	18	0	4	3	15	17	3	4	1
3	8	5	4	3	6	13	8	3	0	9	19	3	2	1	15	18	8	2	1
3	9	3	2	1	6	15	4	2	1	10	12	1	5	0	15	19	5	5	1
3	12	2	4	0	6	16	6	1	2	10	14	5	1	2	16	17	3	6	0
3	14	9	4	1	6	17	5	3	4	10	16	7	5	1	17	18	3	3	0
3	16	1	4	0	6	18	3	1	0	10	17	3	6	0	17	19	7	4	2
3	17	14	3	1	7	8	3	2	0	11	12	2	3	0					
3	18	4	3	0	7	12	2	3	0	11	13	3	7	1					
4	5	6	3	1	7	14	3	5	0	11	14	2	4	1					

Table C.16: EON - Case 7

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	2	16	2	0		3	10	9	3	1	6	10	17	1	1	10	12	10	2
1	3	13	3	0		3	11	15	4	1	6	12	12	2	1	10	16	10	2
1	5	14	4	0		3	12	16	2	1	6	13	13	1	0	10	17	15	3
1	6	15	3	1		3	14	13	2	0	6	15	6	2	0	10	19	18	2
1	7	20	1	0		3	15	18	0	0	6	18	14	2	1	11	12	16	3
1	8	13	3	0		3	16	14	3	0	7	9	14	1	1	11	13	10	1
1	9	13	3	2		3	17	18	4	1	7	10	14	0	0	11	14	16	1
1	10	6	3	1		3	19	10	2	0	7	11	12	0	1	11	17	17	1
1	11	12	3	1		4	5	18	1	0	7	13	16	3	0	12	13	19	2
1	12	15	3	2		4	6	15	7	0	7	15	21	1	1	12	15	9	2
1	13	14	3	0		4	7	16	2	2	7	17	13	0	1	12	16	11	1
1	14	12	1	0		4	11	9	3	0	8	9	12	3	1	12	18	11	2
1	15	7	1	1		4	13	12	0	2	8	11	13	1	2	13	14	13	2
1	17	10	2	1		4	14	13	2	0	8	12	16	3	0	13	15	7	2
1	19	13	2	1		4	15	8	2	1	8	13	17	2	1	13	16	11	1
2	4	13	1	0		4	16	16	2	1	8	14	11	1	1	13	19	13	2
2	6	11	1	0		4	17	12	1	0	8	17	21	1	0	14	17	14	0
2	7	13	1	1		4	18	5	1	0	8	18	19	1	0	14	18	11	1
2	10	8	3	0		5	7	10	1	0	8	19	21	0	0	14	19	12	1
2	12	17	1	1		5	9	18	1	1	9	11	18	2	1	15	16	23	1
2	14	10	1	0		5	10	17	2	1	9	12	22	0	1	15	18	14	1
2	15	19	2	0		5	11	14	1	0	9	13	12	2	1	15	19	16	2
2	18	13	1	0		5	12	15	0	1	9	14	16	0	0	16	17	11	0
3	4	16	0	0		5	13	13	2	0	9	15	13	1	0	16	18	15	1
3	5	13	1	1		5	16	13	0	0	9	16	13	2	0	17	18	9	1
3	6	14	3	1		5	17	12	0	0	9	17	10	0	0	17	19	12	4
3	7	21	1	0		5	18	10	0	0	9	18	13	1	1	18	19	15	2
3	8	11	3	2		5	19	18	0	0	9	19	16	2	0				
3	9	17	0	0		6	7	11	3	2	10	11	13	3	2				

Table C.17: EON - Case 8

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	4	10	3	0	3	15	6	1	1	6	16	7	6	0	10	15	11	2	1
1	6	7	3	0	3	18	9	1	0	6	17	5	4	1	10	16	8	5	0
1	7	8	2	0	3	19	8	5	0	6	18	9	3	1	10	17	5	4	1
1	8	9	3	4	4	5	8	2	1	7	9	9	1	2	10	18	4	4	0
1	9	5	3	0	4	6	3	3	0	7	11	7	5	0	11	13	7	4	0
1	10	3	3	0	4	7	6	0	0	7	13	6	5	0	11	15	3	1	1
1	11	7	1	2	4	9	14	4	0	7	14	4	4	2	11	16	3	2	1
1	14	11	7	1	4	10	7	3	0	7	16	8	2	0	11	17	4	0	3
1	18	10	3	0	4	12	3	3	3	7	17	4	6	0	11	19	5	2	1
1	19	4	5	0	4	16	3	3	0	7	18	10	4	0	12	13	4	5	0
2	3	13	3	0	4	17	6	1	0	7	19	10	3	1	12	15	9	0	1
2	4	4	3	0	4	18	3	2	1	8	9	10	5	0	12	16	5	3	0
2	6	9	5	1	5	8	3	2	0	8	11	10	3	1	12	18	4	4	1
2	7	14	4	2	5	9	5	3	1	8	12	11	4	0	12	19	13	6	2
2	9	12	0	1	5	10	10	3	0	8	13	4	2	0	13	14	10	7	1
2	10	8	2	0	5	11	5	2	1	8	14	7	6	0	13	15	5	2	1
2	12	7	5	0	5	12	7	5	0	8	15	5	4	0	13	16	8	2	0
2	13	8	3	0	5	13	5	2	1	8	16	8	3	1	13	17	8	4	1
2	14	6	5	1	5	14	8	2	0	8	18	2	4	1	14	16	7	0	0
2	15	7	5	1	5	15	9	4	1	8	19	4	2	1	14	18	5	1	1
2	16	4	3	1	5	16	7	4	0	9	10	1	4	0	15	16	10	5	4
2	17	9	6	0	5	17	13	6	4	9	12	5	1	2	15	17	5	4	1
2	19	9	5	0	5	18	2	3	1	9	14	8	2	2	15	18	11	3	0
3	4	4	3	0	5	19	7	3	0	9	15	7	5	0	16	18	8	3	3
3	6	9	3	1	6	7	6	1	0	9	17	7	4	0	17	18	9	5	1
3	11	6	3	0	6	11	6	7	0	9	19	4	2	1	17	19	5	1	2
3	12	3	1	0	6	12	6	5	0	10	11	9	4	0	18	19	2	4	0
3	13	10	6	1	6	14	12	3	1	10	13	4	2	1					
3	14	6	1	0	6	15	5	5	1	10	14	5	5	2					

Table C.18: EON - Case 9

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	2	5	4	2	3	9	6	4	0	5	17	5	1	2	9	17	2	3	1
1	3	4	1	1	3	10	4	5	2	5	18	6	4	1	9	18	4	3	1
1	4	6	3	0	3	11	4	3	1	5	19	6	2	0	9	19	2	6	1
1	5	4	6	0	3	12	7	1	1	6	7	4	2	1	10	13	9	1	1
1	6	3	4	2	3	13	6	3	1	6	9	4	2	1	10	16	7	1	4
1	7	5	2	0	3	15	9	6	0	6	10	6	7	2	10	17	3	4	2
1	9	4	1	2	3	16	3	4	3	6	15	1	1	1	10	18	7	7	1
1	10	2	4	2	3	18	4	4	1	6	16	4	4	2	11	12	4	3	0
1	11	7	1	1	3	19	3	1	0	6	17	5	1	0	11	16	3	3	2
1	13	5	4	0	4	5	6	3	0	6	18	7	8	0	11	17	3	5	2
1	14	5	3	0	4	6	8	3	0	7	8	4	7	1	11	18	3	3	2
1	15	9	5	0	4	7	4	5	2	7	9	7	2	0	11	19	4	4	1
1	17	6	2	0	4	8	2	5	3	7	10	4	4	2	12	13	7	3	1
1	18	2	1	1	4	10	2	3	0	7	11	2	4	1	12	15	10	1	1
1	19	6	6	0	4	11	7	2	2	7	14	4	4	1	12	16	4	4	2
2	6	0	4	0	4	13	6	3	0	7	15	6	3	1	12	17	5	11	3
2	7	4	2	0	4	14	8	3	0	7	18	5	1	1	12	19	9	0	1
2	9	5	4	1	4	15	4	4	1	7	19	6	1	2	14	15	3	2	3
2	10	3	3	1	4	16	11	2	1	8	9	3	7	0	14	16	4	0	0
2	11	4	6	1	4	19	3	3	1	8	10	5	3	4	14	17	3	7	1
2	12	4	2	1	5	7	5	7	2	8	12	6	2	1	14	19	3	4	1
2	14	6	0	1	5	8	6	4	0	8	14	6	4	2	15	16	5	7	0
2	15	5	3	1	5	9	2	3	1	8	15	6	2	2	15	17	4	6	1
2	16	6	1	2	5	10	4	6	2	8	16	5	4	0	15	19	2	1	3
2	17	5	4	0	5	11	5	1	2	8	18	3	7	1	16	18	5	4	2
2	18	6	5	2	5	12	3	4	1	9	11	4	6	1	17	18	4	3	0
3	4	2	1	0	5	14	9	5	2	9	12	6	1	0	17	19	8	6	4
3	6	9	2	1	5	15	2	1	1	9	13	7	2	1					
3	7	6	6	1	5	16	2	0	0	9	14	1	6	0					

C.3 GBN

Table C.19: GBN - Case 1

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	2	20	3	1	3	9	22	3	2	5	14	13	2	0	10	11	17	4	2
1	5	21	1	1	3	14	24	1	3	6	8	21	4	0	10	15	25	5	1
1	8	19	2	0	3	15	27	1	1	6	12	24	2	0	11	15	12	5	1
1	10	19	1	0	3	16	24	1	1	7	8	21	2	1	12	13	11	3	1
1	11	22	2	0	3	17	19	2	1	7	16	20	1	0	12	15	20	3	1
1	12	17	3	0	4	9	21	1	1	8	10	26	1	2	13	15	22	3	0
1	13	16	1	1	4	10	11	1	1	8	12	21	2	1	14	16	28	3	1
1	16	22	3	2	4	11	26	2	2	8	13	24	1	1	14	17	18	1	2
2	4	20	4	0	5	7	22	0	0	8	14	20	1	1	15	17	20	4	1
2	9	19	1	2	5	10	17	2	1	8	15	16	1	0					
2	17	21	4	1	5	11	19	2	1	8	16	17	2	0					
3	7	18	4	1	5	12	18	1	0	9	16	20	4	1					

Table C.20: GBN - Case 2

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	8	13	5	2	3	11	10	5	2	6	10	11	7	1	10	15	9	3	0
1	9	13	6	1	3	14	11	4	2	6	14	10	4	1	10	16	15	5	1
1	12	9	10	1	3	15	9	4	0	6	15	15	4	1	10	17	5	5	2
1	14	5	14	1	3	16	12	12	1	6	16	7	6	2	11	14	8	6	1
2	3	7	5	1	4	6	8	4	0	6	17	19	5	1	12	17	4	4	2
2	6	10	5	1	4	8	8	6	0	7	9	11	2	0	13	14	11	2	4
2	7	11	4	1	4	9	7	4	0	7	17	23	2	1	13	16	8	4	1
2	12	4	3	0	4	10	7	2	1	9	10	10	3	1	14	17	7	4	1
2	13	13	3	0	5	6	13	1	0	9	13	7	5	0	15	16	6	6	0
2	14	10	7	1	5	10	7	1	2	9	14	15	3	1					
2	16	11	7	1	5	12	11	7	1	9	17	11	6	0					
3	6	8	3	2	6	7	11	4	2	10	12	10	8	1					

Table C.21: GBN - Case 3

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	2	13	6	0	4	11	11	5	1	6	11	5	7	1	10	11	3	3	2
1	3	9	2	0	4	12	5	8	0	6	13	4	4	2	10	15	6	4	0
1	11	5	5	1	4	17	7	4	2	6	17	6	7	2	11	12	5	4	1
1	13	9	4	2	5	6	4	3	3	7	10	9	5	2	11	16	8	8	2
2	9	7	2	5	5	7	5	4	0	7	15	7	5	3	12	14	7	3	1
2	10	12	8	3	5	8	7	5	2	8	9	7	4	2	12	15	7	4	3
2	15	10	5	1	5	12	6	3	4	8	10	1	2	0	12	16	11	5	0
3	4	8	4	0	5	13	11	5	2	8	14	5	6	1	14	16	5	6	3
3	5	6	5	2	5	15	7	8	0	8	16	5	6	0	15	17	6	2	2
3	14	7	6	2	5	16	5	6	0	8	17	7	6	0					
4	8	2	6	3	6	9	3	9	4	9	11	10	3	1					
4	9	3	5	2	6	10	8	6	1	9	13	6	2	2					

Table C.22: GBN - Case 4

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	3	12	0	0	3	7	12	5	1	5	12	18	0	0	9	14	17	5	0
1	4	13	4	1	3	10	10	4	1	5	14	16	0	0	9	16	12	1	0
1	6	15	5	1	3	11	18	1	2	5	15	16	2	1	10	11	18	0	1
1	8	16	0	1	3	12	12	2	0	6	8	21	2	1	10	14	19	1	0
1	9	14	0	1	3	13	13	2	2	6	9	10	0	0	10	15	16	1	1
1	15	18	0	1	3	14	15	2	1	6	10	16	1	1	10	16	12	1	2
1	16	21	1	0	3	16	16	1	1	6	13	18	5	2	10	17	12	1	1
1	17	20	2	1	3	17	9	2	2	6	15	18	2	0	11	12	10	4	0
2	5	14	0	1	4	7	17	1	0	7	9	14	1	0	11	13	24	3	0
2	6	10	3	1	4	8	15	3	0	7	12	20	1	1	11	15	22	2	0
2	8	14	2	0	4	10	16	2	1	7	16	17	0	0	11	16	24	2	1
2	10	18	5	1	4	13	22	0	0	7	17	15	3	2	13	14	13	0	0
2	11	17	1	0	4	14	16	3	1	8	11	19	2	0	13	15	12	4	0
2	13	14	1	1	4	16	18	2	1	8	13	14	1	0	13	17	18	4	2
2	15	18	1	0	5	7	14	1	2	8	14	17	0	2	14	15	13	1	1
3	5	11	4	1	5	8	11	1	0	8	16	16	3	1	14	17	18	1	1
3	6	24	1	0	5	10	20	1	0	8	17	15	1	0	16	17	17	2	1

Table C.23: GBN - Case 5

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	6	12	2	1	2	14	8	2	1	4	17	4	7	0	7	13	5	10	0
1	8	5	3	0	2	17	13	5	0	5	7	8	7	2	7	14	7	2	0
1	9	5	5	0	3	4	4	4	4	5	9	4	7	2	7	16	10	2	1
1	10	7	5	0	3	5	9	4	1	5	12	12	4	1	7	17	12	3	0
1	11	13	2	0	3	7	11	1	0	5	13	8	5	1	8	11	5	3	0
1	12	7	4	0	3	8	9	3	2	5	17	3	3	0	8	15	9	1	4
1	15	4	5	1	3	9	6	6	2	6	9	12	4	2	9	17	9	3	1
1	16	5	8	0	3	10	10	5	1	6	10	13	3	0	10	12	7	7	1
1	17	8	4	0	3	12	8	9	0	6	11	7	2	1	10	13	5	3	0
2	5	4	4	0	3	15	4	7	1	6	13	6	1	0	10	15	9	3	0
2	6	7	1	1	3	16	7	2	0	6	14	11	4	0	11	12	9	2	0
2	7	4	3	2	3	17	9	4	0	6	15	4	4	4	11	13	11	4	0
2	9	5	4	2	4	5	15	3	0	6	16	11	2	1	11	14	7	7	2
2	10	8	6	0	4	6	6	5	1	6	17	13	6	0	12	13	4	5	0
2	11	9	4	0	4	12	6	4	1	7	8	7	0	1	13	14	7	3	5
2	12	4	1	0	4	13	14	0	1	7	9	9	3	0	13	15	8	7	0
2	13	11	3	0	4	16	10	3	1	7	10	8	4	1	14	17	9	2	1

Table C.24: GBN - Case 6

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	2	7	3	1	2	17	8	2	1	5	12	3	5	1	9	13	6	3	2
1	5	6	9	4	3	4	3	3	0	5	14	2	3	2	9	14	4	6	3
1	7	4	6	0	3	5	7	6	1	5	16	7	4	3	9	17	5	4	2
1	8	5	8	1	3	7	9	6	2	6	7	3	1	1	10	11	4	2	0
1	9	5	2	2	3	14	1	3	1	6	10	5	3	2	10	12	4	7	1
1	10	3	2	1	3	16	8	6	1	6	11	4	9	1	11	13	6	3	1
1	13	8	4	0	4	5	4	5	2	6	12	5	2	1	11	15	1	1	4
1	14	7	5	0	4	7	8	3	1	6	13	3	3	2	11	16	3	2	1
1	15	6	3	1	4	9	9	5	0	6	17	4	1	1	11	17	7	2	2
1	16	6	1	2	4	10	4	4	1	7	8	10	2	1	12	14	2	5	1
2	3	5	5	0	4	11	5	8	0	7	11	6	2	0	12	15	5	4	1
2	6	9	3	3	4	13	6	2	0	7	15	7	3	2	12	17	7	5	3
2	7	4	2	1	4	14	6	5	2	8	10	9	3	2	13	15	8	3	1
2	9	3	7	2	4	15	5	3	0	8	12	6	3	1	13	17	6	3	1
2	12	7	6	2	4	17	5	3	5	8	14	1	7	0	14	15	4	3	1
2	13	6	5	0	5	6	5	1	2	8	17	4	4	1	14	17	2	2	0
2	14	7	4	0	5	8	5	6	0	9	11	6	4	0	16	17	5	4	0

Table C.25: GBN - Case 7

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	3	12	2	1	3	9	10	1	2	6	13	18	0	0	9	16	14	1	0
1	4	12	2	1	3	10	16	1	0	6	14	14	1	0	9	17	18	3	0
1	5	16	0	1	3	11	19	2	0	6	15	18	1	0	10	12	14	0	1
1	8	20	3	0	3	14	14	1	2	6	16	13	2	0	10	13	11	2	0
1	9	10	1	3	3	17	13	0	1	7	8	22	1	1	10	14	9	1	0
1	11	16	1	1	4	7	10	2	2	7	10	11	2	1	10	15	11	1	1
1	12	14	1	2	4	10	22	1	1	7	11	17	4	0	10	17	18	2	0
1	14	10	2	1	4	11	20	1	0	7	14	19	3	1	11	12	9	0	0
2	3	15	3	0	4	12	16	3	2	7	15	17	0	2	11	13	15	1	0
2	4	14	0	0	4	13	14	1	0	7	16	18	1	0	11	15	10	2	0
2	6	8	2	1	4	15	18	2	1	7	17	20	3	0	11	16	8	1	0
2	7	13	3	0	4	16	19	1	0	8	9	11	2	0	11	17	21	2	1
2	8	8	1	0	5	6	13	1	0	8	11	17	0	1	12	14	16	2	1
2	12	13	1	1	5	10	9	0	0	8	12	21	0	1	12	16	16	1	0
2	13	16	1	0	5	12	10	0	0	8	13	11	1	0	13	14	16	1	0
2	14	11	2	2	5	13	13	3	0	8	15	10	3	0	13	15	12	4	1
2	15	11	2	1	5	14	12	1	1	8	16	13	2	0	13	16	21	2	1
2	16	11	1	1	5	15	13	3	0	8	17	14	1	0	13	17	9	0	1
2	17	18	0	1	5	16	12	2	1	9	10	11	1	1	14	15	11	4	3
3	5	8	4	0	5	17	10	2	0	9	11	13	0	1	14	17	9	3	0
3	6	20	2	0	6	8	4	1	1	9	12	9	0	2	15	17	13	3	1
3	7	14	1	0	6	9	12	3	1	9	13	11	2	1					
3	8	16	3	0	6	10	14	0	0	9	14	14	2	1					

Table C.26: GBN - Case 8

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	3	12	2	2	3	9	8	1	0	6	9	7	3	2	9	11	2	2	1
1	5	2	5	1	3	13	11	1	0	6	10	4	2	3	9	13	6	2	1
1	6	9	6	0	3	14	6	3	1	6	12	4	4	0	9	14	8	5	0
1	7	8	5	0	3	16	7	6	0	6	13	8	2	2	9	17	11	7	1
1	10	4	4	1	3	17	10	4	0	6	15	7	4	1	10	11	4	0	0
1	11	4	3	0	4	6	6	4	1	6	16	7	3	1	10	12	10	6	3
1	12	5	1	0	4	8	11	1	0	7	8	3	6	1	10	15	7	3	1
1	15	9	2	1	4	9	5	4	0	7	9	8	4	0	10	17	6	2	0
1	17	9	1	2	4	10	3	3	2	7	10	10	2	0	11	15	7	2	0
2	3	3	3	0	4	11	6	4	0	7	11	5	3	0	11	16	8	4	0
2	4	5	4	0	4	14	4	2	1	7	12	5	6	0	11	17	6	2	0
2	5	6	4	1	4	15	5	3	0	7	13	4	10	1	12	13	5	1	1
2	8	9	4	0	4	16	10	3	0	7	14	7	3	2	12	15	9	2	0
2	9	6	3	1	5	9	4	2	0	7	15	12	6	0	12	16	5	0	2
2	10	7	0	0	5	10	6	4	0	8	9	10	6	3	12	17	6	5	3
2	11	11	1	1	5	11	8	3	0	8	10	6	9	1	13	14	7	3	0
2	14	5	7	2	5	12	12	1	0	8	11	6	4	1	14	15	5	4	0
2	15	8	2	1	5	14	8	6	0	8	12	11	3	1	14	17	6	4	0
2	17	7	3	2	5	15	7	4	0	8	14	6	1	2	15	16	4	3	0
3	4	8	3	0	5	16	9	3	0	8	15	8	2	1	15	17	7	2	1
3	6	7	2	3	5	17	8	3	0	8	16	3	7	1	16	17	12	0	0
3	7	8	3	0	6	7	5	4	1	8	17	7	5	1					
3	8	10	3	1	6	8	5	6	0	9	10	6	4	0					

Table C.27: GBN - Case 9

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	2	4	8	1	3	7	6	1	1	6	11	5	3	1	9	16	5	5	1
1	4	6	6	1	3	12	9	8	2	6	12	3	6	2	10	11	6	5	1
1	5	8	6	1	3	13	3	4	0	6	13	4	3	2	10	12	7	1	1
1	6	3	2	0	3	15	2	3	2	6	14	8	1	1	10	13	3	2	1
1	7	3	0	0	3	16	8	6	0	6	16	4	1	0	10	14	1	1	0
1	10	10	6	1	4	5	3	6	1	6	17	5	4	0	11	13	4	4	0
1	11	9	5	1	4	8	3	2	0	7	8	3	2	0	11	14	6	1	3
1	12	9	4	1	4	9	10	1	2	7	9	5	5	2	11	15	4	4	0
1	13	5	4	0	4	12	6	1	1	7	12	6	4	2	11	16	6	3	1
1	15	9	2	1	4	16	4	2	0	7	14	8	4	1	12	13	5	1	0
1	16	6	4	3	4	17	3	1	1	7	15	4	5	2	12	14	6	6	5
1	17	4	8	1	5	6	5	2	1	7	16	5	2	0	12	15	3	4	0
2	4	3	6	1	5	7	5	5	0	7	17	4	2	2	12	16	5	2	0
2	5	6	4	0	5	8	3	1	2	8	9	3	4	1	12	17	5	4	1
2	7	2	4	3	5	9	4	4	0	8	10	3	0	1	13	14	5	2	1
2	10	4	4	1	5	13	2	5	3	8	12	3	1	0	13	15	3	6	1
2	11	2	3	1	5	14	4	6	1	8	13	3	4	0	13	17	3	5	1
2	13	3	5	1	5	15	1	5	0	8	14	2	3	1	14	15	8	2	1
2	14	4	2	3	5	16	0	3	3	8	15	5	4	3	14	16	4	2	0
2	16	7	5	1	5	17	2	2	2	8	17	3	0	2	14	17	6	2	1
3	4	3	2	1	6	7	4	3	1	9	13	3	7	2	15	16	5	1	0
3	5	7	3	0	6	8	3	4	2	9	14	2	0	1					
3	6	4	3	1	6	10	7	0	2	9	15	5	5	1					

C.4 NSF

Table C.28: NSF - Case 1

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	2	15	2	0	2	14	12	2	1	4	12	19	2	1	8	12	25	0	1
1	7	16	3	1	3	5	14	3	0	4	13	23	1	0	8	14	15	5	0
1	8	20	1	0	3	8	18	1	2	5	6	21	1	0	9	10	15	2	0
1	9	22	2	1	3	9	20	1	0	5	9	25	3	0	9	11	21	1	2
2	3	20	3	0	3	11	24	1	1	5	13	26	0	1	9	14	15	3	0
2	7	30	2	2	3	13	21	1	1	6	13	15	1	1	13	14	17	2	1
2	9	15	2	1	3	14	26	2	1	7	10	15	1	1					
2	11	31	0	0	4	11	24	1	1	8	11	20	1	0					

Table C.29: NSF - Case 2

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	4	7	3	0	3	9	8	4	2	6	9	9	4	2	10	11	9	5	1
1	5	8	8	0	4	6	8	7	1	6	12	8	3	1	11	12	2	5	1
2	6	14	4	1	4	9	9	11	1	6	13	12	6	0	11	13	8	6	1
2	12	15	6	0	4	12	13	5	0	7	8	14	4	1	11	14	6	5	1
3	4	11	4	1	4	13	15	4	1	7	14	13	6	0	12	13	11	4	0
3	5	11	5	1	5	6	7	3	0	8	14	9	8	3	12	14	10	5	1
3	7	11	5	0	5	7	2	5	2	9	13	16	4	1					
3	8	11	3	0	5	9	9	3	1	9	14	14	5	1					

Table C.30: NSF - Case 3

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	2	7	7	0	2	4	5	6	3	3	13	8	4	1	6	11	7	2	3
1	5	5	5	1	2	8	6	5	3	3	14	10	8	3	6	13	9	6	3
1	6	8	5	1	2	9	4	4	0	4	7	6	5	0	7	10	6	1	0
1	7	8	3	2	2	10	11	6	1	4	9	3	4	1	9	13	4	6	1
1	9	9	3	1	2	11	11	5	0	4	14	8	7	2	10	11	6	7	1
1	11	4	9	2	2	12	11	6	2	5	7	8	6	2	11	14	3	4	1
1	12	5	4	1	2	14	4	1	0	5	11	2	5	1					
2	3	6	7	1	3	9	12	7	2	6	9	4	2	1					

Table C.31: NSF - Case 4

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	2	15	3	0	2	13	16	0	1	5	8	22	1	0	8	14	18	2	1
1	5	17	2	2	2	14	19	0	1	5	11	15	0	1	9	10	23	2	1
1	6	16	2	0	3	5	18	1	0	5	12	21	3	0	9	11	23	2	1
1	10	17	3	0	3	6	18	1	1	6	7	20	3	0	9	12	16	4	1
1	11	14	2	1	3	9	13	0	0	6	8	17	1	1	9	14	21	1	2
1	12	19	0	1	3	10	14	1	0	6	9	13	3	1	10	11	17	0	0
1	13	15	3	0	3	12	23	0	0	6	10	11	1	0	10	14	14	2	0
1	14	14	0	0	3	14	21	3	0	6	12	23	0	1	11	13	21	2	2
2	8	17	0	1	4	8	19	1	1	6	13	9	2	0	11	14	17	1	0
2	9	15	0	0	4	10	12	2	0	6	14	27	1	1					
2	10	20	5	0	4	14	16	1	1	7	12	13	0	1					
2	11	15	1	1	5	6	19	1	1	7	13	17	2	0					

Table C.32: NSF - Case 5

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	2	6	7	0	2	12	6	5	1	5	12	10	4	0	9	11	9	5	1
1	5	6	4	0	2	14	4	7	1	5	14	10	5	0	9	12	13	3	2
1	7	11	5	0	3	8	4	7	0	6	7	6	4	1	9	13	9	6	1
1	8	15	0	2	3	11	7	6	0	6	10	8	3	0	9	14	11	6	0
1	10	8	1	0	3	14	7	6	0	6	11	9	3	0	10	11	13	4	0
1	11	12	5	0	4	8	12	7	0	6	14	8	0	1	10	12	8	4	1
1	12	7	2	1	4	10	10	2	1	7	9	12	2	2	10	13	8	5	1
1	13	4	4	1	4	11	8	4	0	7	13	3	4	1	10	14	5	4	1
1	14	4	6	0	5	7	10	3	0	7	14	9	3	2	12	14	14	4	1
2	6	9	6	1	5	9	11	5	1	8	11	12	6	2					
2	10	8	4	1	5	10	12	8	1	8	13	4	4	2					
2	11	10	4	0	5	11	14	4	2	9	10	4	4	1					

Table C.33: NSF - Case 6

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	2	3	0	1	2	6	7	1	1	4	11	4	7	0	7	11	6	4	1
1	3	1	6	0	2	7	5	3	1	4	14	6	4	2	7	14	4	4	0
1	4	6	2	1	2	9	4	5	0	5	6	9	3	0	9	11	10	6	0
1	5	6	4	2	2	11	6	4	2	5	7	11	6	2	9	12	4	7	2
1	8	7	2	0	3	4	5	6	1	5	9	1	7	2	9	14	4	4	3
1	9	4	5	0	3	8	8	7	1	6	7	6	4	2	10	11	4	7	0
1	11	8	2	0	3	11	7	3	0	6	9	5	4	1	10	14	7	0	1
1	13	5	9	2	3	12	2	3	3	6	12	6	6	1	11	14	7	5	1
1	14	3	5	2	3	13	5	3	2	6	13	7	2	3	12	13	6	5	1
2	3	9	6	3	3	14	8	4	2	6	14	8	3	0					
2	4	8	6	0	4	7	9	3	2	7	8	3	3	3					
2	5	6	7	0	4	9	4	6	1	7	9	6	2	0					

Table C.34: NSF - Case 7

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	3	27	2	0	2	12	18	1	1	4	11	16	0	0	8	9	18	1	1
1	4	17	0	1	2	13	13	1	2	4	12	17	0	0	8	10	15	0	1
1	5	17	1	0	2	14	20	1	2	5	6	18	2	0	8	11	21	2	2
1	6	19	2	0	3	4	13	1	2	5	7	12	0	0	9	10	15	3	0
1	7	15	3	2	3	6	13	0	1	5	9	15	0	1	9	11	17	5	1
1	9	18	4	1	3	7	15	1	0	5	13	10	2	1	9	12	27	1	0
1	10	21	5	0	3	8	12	1	1	6	7	13	2	0	9	14	10	0	0
1	11	18	1	0	3	11	19	1	0	6	8	21	1	0	10	11	15	0	1
1	13	17	0	0	3	12	20	1	1	6	11	21	4	0	10	12	25	0	0
1	14	18	2	1	3	13	16	0	0	6	12	25	1	1	10	14	18	3	0
2	7	14	2	1	3	14	16	2	0	6	13	19	0	1	11	12	24	1	2
2	8	14	1	1	4	5	17	1	0	7	8	11	0	0	11	14	17	1	0
2	9	16	2	0	4	6	12	1	0	7	9	14	3	0	12	13	18	2	1
2	10	11	0	0	4	7	16	0	3	7	10	13	2	0	12	14	18	1	0
2	11	15	5	0	4	10	26	2	0	7	13	15	2	1	13	14	13	2	0

Table C.35: NSF - Case 8

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	3	10	3	0	3	6	12	4	1	5	8	11	3	1	8	11	7	5	0
1	4	10	3	0	3	7	8	4	1	5	9	6	6	1	8	12	8	6	0
1	5	3	5	1	3	9	10	6	3	5	13	14	5	0	8	14	18	5	1
1	6	10	5	0	3	10	8	8	0	5	14	12	5	1	9	10	9	2	0
1	7	9	7	0	3	13	9	8	1	6	7	8	4	1	9	12	9	1	0
1	9	5	5	1	4	5	9	4	1	6	8	8	4	1	9	13	6	4	0
1	11	7	1	0	4	6	4	2	2	6	12	6	6	0	9	14	6	8	0
1	13	8	4	1	4	7	10	6	1	6	13	9	5	2	10	11	5	6	0
2	5	14	5	1	4	8	9	7	1	6	14	9	5	0	10	12	5	2	4
2	7	11	6	0	4	10	8	5	0	7	8	10	5	2	10	13	11	5	1
2	9	10	4	0	4	11	7	1	2	7	9	7	3	0	10	14	8	2	2
2	10	7	4	1	4	12	11	6	1	7	11	5	2	0	11	12	10	2	1
2	12	5	5	1	4	13	15	3	0	7	13	9	7	0	11	14	6	5	0
2	13	8	3	1	5	6	8	2	0	8	9	10	2	1	12	13	9	3	1
3	5	8	2	1	5	7	2	3	0	8	10	8	0	0	12	14	3	5	1

Table C.36: NSF - Case 9

Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100	Ni	Nf	10	40	100
1	2	4	4	4	3	5	5	3	2	4	13	5	4	0	8	9	3	8	1
1	5	6	6	1	3	8	7	4	2	5	6	7	5	1	8	10	8	7	1
1	6	9	3	1	3	9	4	5	2	5	9	11	3	2	8	11	3	3	0
1	7	8	6	1	3	10	8	5	1	5	10	9	5	2	8	13	6	1	2
1	8	8	4	2	3	11	7	5	1	5	12	6	3	0	8	14	3	3	3
1	9	8	3	1	3	12	7	4	2	5	14	7	6	0	9	12	3	3	1
1	12	3	5	1	3	13	5	8	1	6	7	9	3	2	9	13	8	5	0
1	13	4	4	0	3	14	6	5	2	6	9	7	7	2	9	14	6	2	0
1	14	7	4	2	4	5	3	5	2	6	11	5	4	2	10	11	7	6	3
2	3	3	4	4	4	6	8	3	0	6	12	6	5	0	10	12	8	4	0
2	4	4	5	1	4	7	7	1	0	6	13	1	6	2	10	13	6	5	0
2	5	1	5	0	4	8	4	3	1	6	14	2	3	1	10	14	3	3	2
2	9	5	3	1	4	9	8	4	4	7	8	4	4	0	11	13	4	6	0
2	12	7	5	0	4	10	2	2	0	7	11	6	4	1	12	14	5	3	1
2	14	9	2	0	4	12	4	1	0	7	12	4	5	0	13	14	5	7	0

Appendix D

Full Results

D.1 GEANT2, Given 60 Seconds

Symbol	Name
$\#T$	Number of Threads
t_E	Time of Execution
C	Best Cost Solution found
CA	Highest Channel Assigned
t_{sol}	Found Solution Time
$\#i$	Number of Iterations
$\#IS$	Number of Invalid Solutions
$\#G_U$	Number of Greedy Solutions Unfeasible
$\#LS_U$	Number of Local Search Solutions Unfeasible
UD	Unfeasible Degree
$\#IM$	Number of Invert Multiplex used
C_{IM}	Cost % of Invert Multiplex
$\#MX$	Number of Muxponders placed
C_{MX}	Cost % of Muxponders
$\#TX$	Number of Transponders placed
C_{TX}	Cost % of Transponders
$\#3R$	Number of $3R$ regenerators placed
C_{3R}	Cost % of $3R$ regenerators
#10	Number of Multi-Hop Grooming of $10Gb/s$
%10	Traffic % of Multi-Hop Grooming of $10Gb/s$
#40	Number of Multi-hop Grooming of $40Gb/s$
%40	Traffic % of Multi-hop Grooming of $40Gb/s$
$\bar{m}F$	Average Fragmentation at Channel Assigned
MF	Max Fragmentation at Channel Assigned
C_{IM}	Cost of Invert Multiplexers
C_{MX}	Cost of Multiplexers
C_{TX}	Cost of Transponders
C_{3R}	Cost of $3R$ regenerators

Table D.1: Header symbols and their description.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.64	7660.8	64	3.65	160	0	0	0	0	16	4.18	530	37.72	298	30.15	196	27.94	61	6.10	0	0.00	13.62	45	3200	28900	23100	21408
1	61.06	7737.2	65	53.87	159	0	0	0	0	14	3.62	546	37.97	300	30.24	197	28.17	58	5.80	0	0.00	13.42	47	2800	29380	23400	21792
1	60.47	7714.0	62	30.73	156	0	0	0	0	10	2.59	538	37.36	304	31.11	204	28.93	50	5.00	0	0.00	11.12	44	2000	28820	24000	22320
1	60.86	7754.0	61	10.58	162	0	0	0	0	14	3.61	534	37.74	300	30.18	200	28.48	47	4.70	0	0.00	12.44	40	2800	29260	23400	22080
1	60.64	7751.2	63	23.62	153	0	0	0	0	16	4.13	526	37.65	298	29.80	204	28.42	65	6.50	0	0.00	13.56	45	3200	29180	23100	22032
1	61.03	7701.6	64	10.66	157	0	0	0	0	12	3.12	538	37.63	302	30.77	200	28.48	54	5.40	0	0.00	13.58	46	2400	28980	23700	21936
1	60.79	7724.0	66	33.27	162	0	0	0	0	14	3.63	552	37.80	300	30.30	202	28.28	55	5.50	0	0.00	12.38	41	2800	29200	23400	21840
1	61.29	7713.6	63	28.16	155	0	0	0	0	14	3.63	540	37.91	300	30.34	196	28.13	66	6.60	0	0.00	13.19	44	2800	29240	23400	21696
1	60.53	7721.6	61	32.74	155	0	0	0	0	10	2.59	536	37.61	304	31.08	198	28.72	66	6.60	0	0.00	11.92	42	2000	29040	24000	22176
1	60.84	7726.0	63	31.98	159	0	0	0	0	16	4.14	536	37.38	298	29.90	200	28.58	66	6.60	0	0.00	12.31	45	3200	28880	23100	22080
12	61.50	7704.4	65	3.98	1625	0	0	0	0	20	5.18	536	38.23	294	29.14	195	27.23	69	6.90	0	0.00	13.44	47	4000	29520	22500	21024
12	60.86	7710.4	62	21.36	1729	0	0	0	0	10	2.59	536	38.08	304	31.13	195	28.20	65	6.50	0	0.00	11.73	44	2000	29360	24000	21744
12	61.45	7694.8	60	51.54	1643	0	0	0	0	12	3.11	536	37.84	302	30.71	197	28.05	61	6.10	0	0.00	10.85	41	2400	29200	23700	21648
12	60.78	7724.4	61	45.88	1652	0	0	0	0	14	3.62	530	37.58	300	30.26	199	28.43	58	5.80	0	0.00	12.33	42	2800	29060	23400	21984
12	61.42	7588.0	63	6.79	1644	0	0	0	0	14	3.61	536	37.42	300	30.15	188	26.60	59	5.90	0	0.00	13.46	46	2800	29040	23400	20640
12	60.76	7682.0	64	26.10	1730	0	0	0	0	16	4.17	532	37.33	298	30.07	202	28.43	54	5.40	0	0.00	12.33	47	3200	28680	23100	21840
12	61.54	7702.8	66	33.93	1659	0	0	0	0	16	4.12	540	37.48	298	29.77	200	27.90	56	5.60	0	0.00	13.44	44	3200	29080	23100	21648
12	61.46	7685.6	65	24.13	1600	0	0	0	0	14	3.62	544	37.47	300	30.28	202	28.07	67	6.70	0	0.00	15.19	46	2800	28960	23400	21696
12	61.26	7702.0	65	35.58	1720	0	0	0	0	16	4.14	536	37.99	298	29.89	197	27.64	59	5.90	0	0.00	13.08	44	3200	29360	23100	21360
12	61.57	7690.0	63	44.77	1725	0	0	0	0	12	3.12	528	37.60	302	30.77	196	28.36	55	5.50	0	0.00	12.37	44	2400	28960	23700	21840
36	77.39	7704.0	63	7.16	2170	0	0	0	0	16	4.11	538	37.46	298	29.70	198	27.77	59	5.90	0	0.00	12.69	44	3200	29140	23100	21600
36	74.94	7681.6	64	39.62	2106	0	0	0	0	14	3.60	532	36.92	300	30.12	203	28.24	49	4.90	0	0.00	12.50	44	2800	28680	23400	21936
36	73.54	7662.4	66	47.19	1862	0	0	0	0	16	4.11	522	37.01	298	29.67	197	27.62	54	5.40	0	0.00	13.08	48	3200	28820	23100	21504
36	73.29	7694.4	63	23.79	2057	0	0	0	0	14	3.61	532	37.38	300	30.17	198	28.03	57	5.70	0	0.00	13.56	44	2800	29000	23400	21744
36	72.98	7668.8	64	14.29	2042	0	0	0	0	16	4.11	538	37.26	298	29.70	199	27.52	57	5.70	0	0.00	12.85	46	3200	28980	23100	21408
36	67.55	7694.4	67	18.08	1783	0	0	0	0	16	4.13	538	37.57	298	29.78	200	27.73	66	6.60	0	0.00	14.71	49	3200	29140	23100	21504
36	78.39	7679.2	64	57.83	2210	0	0	0	0	18	4.63	532	37.68	296	29.30	194	27.08	62	6.20	0	0.00	12.71	45	3600	29320	22800	21072
36	69.12	7704.4	62	55.21	1962	0	0	0	0	16	4.12	532	37.95	298	29.74	193	27.38	61	6.10	0	0.00	11.65	45	3200	29480	23100	21264
36	72.65	7690.0	62	32.68	2040	0	0	0	0	14	3.60	542	37.69	300	30.06	197	27.44	64	6.40	0	0.00	12.63	46	2800	29340	23400	21360
36	67.47	7704.4	65	19.03	1930	0	0	0	0	20	5.15	536	38.04	294	28.99	195	27.09	69	6.90	0	0.00	13.44	47	4000	29520	22500	21024
36*	61.54	7692.4	62	48.49	1754	0	0	0	0	14	3.64	530	37.36	300	30.42	199	28.58	50	5.00	0	0.00	11.54	44	2800	28740	23400	21984
36*	62.03	7588.0	63	27.30	1744	0	0	0	0	14	3.69	536	38.27	300	30.84	188	27.20	59	5.90	0	0.00	13.46	46	2800	29040	23400	20640
36*	62.01	7726.4	62	16.55	1734	0	0	0	0	12	3.11	534	37.46	302	30.67	200	28.76	60	6.00	0	0.00	12.65	43	2400	28940	23700	22224
36*	62.13	7702.8	66	33.82	1736	0	0	0	0	16	4.15	540	37.75	298	29.99	200	28.10	56	5.60	0	0.00	13.44	44	3200	29080	23100	21648
36*	61.60	7684.0	63	10.65	1627	0	0	0	0	18	4.69	540	37.84	296	29.67	200	27.80	62	6.20	0	0.00	12.42	43	3600	29080	22800	21360
36*	61.99	7701.6	67	31.86	1769	0	0	0	0	20	5.19	546	37.73	294	29.21	201	27.86	60	6.00	0	0.00	13.81	47	4000	29060	22500	21456
36*	61.53	7696.0	61	19.53	1729	0	0	0	0	14	3.64	532	37.89	300	30.41	198	28.07	58	5.80	0	0.00	12.67	44	2800	29160	23400	21600
36*	62.15	7681.6	64	58.30	1759	0	0	0	0	14	3.65	532	37.34	300	30.46	203	28.56	49	4.90	0	0.00	12.50	44	2800	28680	23400	21936
36*	61.62	7662.4	66	47.44	1734	0	0	0	0	16	4.18	522	37.61	298	30.15	197	28.06	54	5.40	0	0.00	13.08	48	3200	28820	23100	21504
36*	61.90	7694.4	63	59.62	1707	0	0	0	0	14	3.64	532	37.69	300	30.41	198	28.26	57	5.70	0	0.00	13.56	44	2800	29000	23400	21744

Table D.2: Results of all runs made with GEANT2 network case 1, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.59	8001.6	78	53.73	160	0	119	0	0	8	2.00	332	21.02	562	49.57	203	27.41	56	11.20	0	0.00	16.46	62	1600	16820	39660	21936
1	61.31	8024.4	79	4.31	165	0	126	0	0	12	2.99	322	20.34	558	48.68	213	27.99	51	10.20	0	0.00	19.19	61	2400	16320	39060	22464
1	60.61	8006.8	76	57.86	165	0	128	0	0	6	1.50	322	20.66	560	49.61	207	28.24	43	8.60	0	0.00	17.58	59	1200	16540	39720	22608
1	60.93	8052.0	80	16.35	163	0	118	0	0	12	2.98	314	19.90	562	48.81	212	28.32	51	10.20	0	0.00	17.29	61	2400	16020	39300	22800
1	60.93	8030.0	79	51.32	162	0	127	0	0	12	2.99	326	21.32	552	48.19	209	27.50	50	10.00	0	0.00	19.56	63	2400	17120	38700	22080
1	60.57	8022.8	80	58.72	164	0	130	0	0	12	2.99	320	20.14	562	48.99	209	27.88	49	9.80	0	0.00	20.04	60	2400	16160	39300	22368
1	61.12	8005.6	77	37.28	165	0	131	0	0	8	2.00	320	20.46	562	49.54	208	28.00	53	10.60	0	0.00	17.27	61	1600	16380	39660	22416
1	60.70	8020.4	79	8.80	163	0	125	0	0	10	2.49	328	21.47	554	48.63	205	27.41	51	10.20	0	0.00	17.25	54	2000	17220	39000	21984
1	61.01	8020.0	80	30.81	159	0	129	0	0	12	2.99	324	20.47	558	48.70	210	27.83	54	10.80	0	0.00	18.33	64	2400	16420	39060	22320
1	60.76	8036.8	79	19.62	166	0	123	0	0	14	3.48	326	20.75	556	48.23	211	27.53	52	10.40	0	0.00	17.69	64	2800	16680	38760	22128
12	60.89	7971.6	77	1.08	1786	0	1389	0	0	8	1.99	318	20.23	562	49.29	201	27.56	53	10.60	0	0.00	16.85	59	1600	16280	39660	22176
12	61.21	7958.4	79	40.40	1786	0	1359	0	0	10	2.51	320	20.10	564	49.76	208	27.62	55	11.00	0	0.00	17.40	57	2000	16000	39600	21984
12	60.81	7966.4	76	13.09	1794	0	1364	0	0	10	2.51	320	20.46	564	49.64	201	27.26	56	11.20	0	0.00	17.48	61	2000	16320	39600	21744
12	61.04	7968.4	80	31.90	1800	0	1365	0	0	10	2.49	332	20.98	560	49.10	203	26.83	52	10.40	0	0.00	18.54	65	2000	16820	39360	21504
12	60.98	7958.4	78	15.09	1752	0	1309	0	0	8	1.99	316	20.34	562	49.38	202	27.37	54	10.80	0	0.00	16.46	54	1600	16340	39660	21984
12	61.34	7970.8	79	19.33	1761	0	1326	0	0	6	1.49	324	21.18	558	49.29	198	27.24	48	9.60	0	0.00	18.29	61	1200	17020	39600	21888
12	60.75	7926.0	79	50.83	1686	0	1302	0	0	10	2.51	320	20.89	554	48.90	201	27.08	50	10.00	0	0.00	18.87	62	2000	16660	39000	21600
12	61.37	7977.2	79	36.74	1802	0	1368	0	0	10	2.49	318	19.79	564	49.28	208	27.72	53	10.60	0	0.00	17.62	49	2000	15900	39600	22272
12	60.95	7973.2	79	40.70	1683	0	1289	0	0	10	2.49	324	20.62	560	48.95	203	27.10	52	10.40	0	0.00	18.10	62	2000	16580	39360	21792
12	61.25	7976.4	78	48.08	1795	0	1383	0	0	12	2.99	314	20.00	558	48.59	206	27.65	55	11.00	0	0.00	18.92	54	2400	16080	39060	22224
36	72.24	7986.0	80	8.21	2122	0	1605	0	0	12	2.99	322	21.10	552	48.27	205	27.24	49	9.80	0	0.00	18.88	56	2400	16920	38700	21840
36	68.00	7920.4	78	10.92	1955	0	1519	0	0	14	3.49	328	20.69	556	48.25	198	26.17	62	12.40	0	0.00	18.77	55	2800	16620	38760	21024
36	67.63	7965.2	79	25.33	1959	0	1504	0	0	8	1.99	318	20.09	562	49.42	208	27.75	52	10.40	0	0.00	19.69	63	1600	16120	39660	22272
36	73.07	7967.2	79	38.38	2174	0	1659	0	0	12	2.98	324	20.41	558	48.56	206	27.09	49	9.80	0	0.00	18.69	60	2400	16420	39060	21792
36	74.08	7966.0	79	36.86	2172	0	1694	0	0	10	2.48	320	20.14	560	48.87	209	27.41	50	10.00	0	0.00	18.87	56	2000	16220	39360	22080
36	72.57	7955.6	76	35.48	2158	0	1645	0	0	12	2.97	330	21.75	546	47.38	200	26.22	52	10.40	0	0.00	17.23	59	2400	17600	38340	21216
36	73.35	7983.2	80	50.61	2174	0	1624	0	0	8	1.99	326	20.23	566	49.52	204	27.34	52	10.40	0	0.00	17.46	65	1600	16300	39900	22032
36	74.04	7968.8	77	47.63	2198	0	1688	0	0	12	2.98	322	20.01	562	48.84	207	27.20	46	9.20	0	0.00	17.92	55	2400	16100	39300	21888
36	68.02	7978.0	78	31.28	1997	0	1527	0	0	10	2.48	322	20.00	564	49.20	209	27.43	50	10.00	0	0.00	18.10	62	2000	16100	39600	22080
36	76.16	7912.8	80	17.94	2182	0	1681	0	0	10	2.48	326	21.02	554	48.34	198	26.24	57	11.40	0	0.00	18.81	56	2000	16960	39000	21168
36*	61.68	7978.8	80	50.50	1812	0	1389	0	0	12	3.01	328	21.66	548	48.20	206	27.13	45	9.00	0	0.00	18.15	65	2400	17280	38460	21648
36*	62.01	7985.6	79	51.22	1707	0	1305	0	0	12	3.01	326	20.61	562	49.21	205	27.17	54	10.80	0	0.00	16.81	54	2400	16460	39300	21696
36*	61.45	7965.6	77	3.26	1787	0	1369	0	0	14	3.52	320	21.04	554	48.51	201	26.94	50	10.00	0	0.00	18.00	57	2800	16760	38640	21456
36*	61.45	7986.0	80	48.06	1788	0	1355	0	0	12	3.01	322	21.19	552	48.46	205	27.35	49	9.80	0	0.00	18.88	56	2400	16920	38700	21840
36*	61.90	7920.4	78	53.23	1820	0	1410	0	0	14	3.54	328	20.98	556	48.94	198	26.54	62	12.40	0	0.00	18.77	55	2800	16620	38760	21024
36*	61.32	7962.8	79	10.55	1702	0	1280	0	0	12	3.01	316	19.84	562	49.35	208	27.79	48	9.60	0	0.00	19.12	61	2400	15800	39300	22128
36*	61.95	7996.4	80	9.27	1779	0	1368	0	0	12	3.00	318	20.36	558	48.85	209	27.79	53	10.60	0	0.00	18.96	64	2400	16280	39060	22224
36*	61.59	7976.4	77	51.56	1778	0	1349	0	0	10	2.51	326	21.19	556	49.04	201	27.26	56	11.20	0	0.00	16.88	60	2000	16900	39120	21744
36*	62.40	7962.8	79	32.04	1793	0	1400	0	0	14	3.52	326	21.98	546	47.92	198	26.58	51	10.20	0	0.00	17.10	59	2800	17500	38160	21168
36*	61.42	7979.2	80	30.92	1745	0	1380	0	0	12	3.01	326	20.43	562	49.25	206	27.31	56	11.20	0	0.00	18.77	65	2400	16300	39300	21792

Table D.3: Results of all runs made with GEANT2 network case 2, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.76	8874.8	80	43.54	162	0	159	0	0	34	7.66	274	15.62	600	50.71	206	26.02	62	15.50	0	0.00	18.63	73	6800	13860	45000	23088
1	61.18	8864.4	78	1.48	162	0	161	0	0	40	9.02	272	15.34	594	49.75	215	25.88	59	14.75	0	0.00	16.96	64	8000	13600	44100	22944
1	60.62	8916.8	80	8.14	158	0	154	0	0	32	7.18	278	15.59	602	50.80	211	26.43	50	12.50	0	0.00	17.46	64	6400	13900	45300	23568
1	61.03	8875.2	80	49.44	161	0	159	0	0	36	8.11	274	15.62	598	50.37	208	25.91	56	14.00	0	0.00	16.12	66	7200	13860	44700	22992
1	60.65	8869.6	80	40.62	162	0	154	0	0	34	7.67	280	15.78	600	50.74	207	25.81	54	13.50	0	0.00	18.27	66	6800	14000	45000	22896
1	61.21	8878.4	78	7.83	158	0	155	0	0	36	8.11	274	15.43	598	50.35	210	26.11	68	17.00	0	0.00	16.19	62	7200	13700	44700	23184
1	60.50	8859.2	80	57.31	157	0	155	0	0	36	8.13	274	15.46	598	50.46	208	25.95	61	15.25	0	0.00	17.69	64	7200	13700	44700	22992
1	61.09	8907.6	80	49.45	159	0	155	0	0	36	8.08	276	15.49	598	50.18	212	26.24	55	13.75	0	0.00	15.42	60	7200	13800	44700	23376
1	60.68	8884.0	79	20.16	162	0	156	0	0	36	8.10	278	15.65	598	50.32	210	25.93	54	13.50	0	0.00	17.52	64	7200	13900	44700	23040
1	60.86	8893.6	80	39.94	161	0	160	0	0	38	8.55	276	15.52	596	49.92	214	26.01	58	14.50	0	0.00	17.00	65	7600	13800	44400	23136
12	61.28	8839.6	79	53.27	1763	0	1738	0	0	32	7.22	276	15.56	602	51.08	204	25.82	54	13.50	0	0.00	18.71	72	6400	13800	45300	22896
12	60.81	8810.0	80	21.97	1668	0	1636	0	0	36	8.17	268	15.21	598	50.74	206	25.88	51	12.75	0	0.00	16.50	66	7200	13400	44700	22800
12	61.34	8821.6	80	48.89	1745	0	1706	0	0	36	8.12	278	15.68	598	50.42	202	25.28	60	15.00	0	0.00	19.94	71	7200	13900	44700	22416
12	61.28	8814.8	78	33.65	1753	0	1719	0	0	34	7.68	270	15.25	600	50.82	205	25.80	52	13.00	0	0.00	16.37	62	6800	13500	45000	22848
12	60.96	8844.8	80	33.77	1668	0	1636	0	0	36	8.10	274	15.42	598	50.31	205	25.71	53	13.25	0	0.00	17.35	68	7200	13700	44700	22848
12	61.18	8831.6	79	32.40	1734	0	1709	0	0	40	9.02	276	15.55	594	49.70	208	25.26	57	14.25	0	0.00	18.37	65	8000	13800	44100	22416
12	61.04	8831.2	80	52.60	1730	0	1701	0	0	42	9.48	272	15.35	592	49.44	203	25.41	52	13.00	0	0.00	16.87	54	8400	13600	43800	22512
12	61.21	8777.2	79	23.84	1745	0	1697	0	0	36	8.14	272	15.38	598	50.57	199	25.19	55	13.75	0	0.00	18.42	63	7200	13600	44700	22272
12	61.26	8811.6	80	24.54	1727	0	1699	0	0	38	8.54	274	15.39	596	49.87	202	25.18	64	16.00	0	0.00	18.79	65	7600	13700	44400	22416
12	60.82	8820.0	78	54.09	1725	0	1688	0	0	34	7.68	272	15.37	600	50.85	206	25.76	58	14.50	0	0.00	15.25	60	6800	13600	45000	22800
36	74.52	8816.4	79	27.38	2053	0	2010	0	0	36	8.06	268	15.18	598	50.05	205	25.42	61	15.25	0	0.00	16.69	65	7200	13560	44700	22704
36	68.42	8806.0	79	23.93	1972	0	1935	0	0	36	8.09	272	15.28	598	50.23	202	25.35	55	13.75	0	0.00	19.31	67	7200	13600	44700	22560
36	74.58	8821.2	80	36.18	2160	0	2127	0	0	34	7.61	278	15.56	600	50.38	203	25.20	59	14.75	0	0.00	18.79	66	6800	13900	45000	22512
36	72.79	8840.0	77	19.72	2059	0	2014	0	0	36	8.13	274	15.46	598	50.45	206	25.73	54	13.50	0	0.00	15.67	64	7200	13700	44700	22800
36	73.79	8827.6	80	2.50	2130	0	2089	0	0	42	9.40	278	15.55	592	49.01	204	24.81	64	16.00	0	0.00	17.88	67	8400	13900	43800	22176
36	67.35	8821.6	80	59.66	1902	0	1853	0	0	36	8.02	278	15.48	598	49.78	202	24.96	57	14.25	0	0.00	17.02	60	7200	13900	44700	22416
36	73.66	8812.0	78	1.20	2089	0	2052	0	0	44	9.91	270	15.21	590	49.00	207	25.14	54	13.50	0	0.00	14.62	52	8800	13500	43500	22320
36	67.20	8844.8	80	34.01	1947	0	1910	0	0	32	7.21	278	15.65	602	51.01	205	25.73	61	15.25	0	0.00	18.85	64	6400	13900	45300	22848
36	67.72	8839.6	79	53.54	1943	0	1912	0	0	32	7.22	276	15.56	602	51.08	204	25.82	54	13.50	0	0.00	18.71	72	6400	13800	45300	22896
36	77.22	8825.2	79	50.59	2220	0	2166	0	0	34	7.65	274	15.41	600	50.62	204	25.60	52	13.00	0	0.00	17.27	68	6800	13700	45000	22752
36*	62.13	8835.6	80	15.19	1783	0	1737	0	0	32	7.24	280	15.85	602	51.27	200	25.64	55	13.75	0	0.00	16.90	64	6400	14000	45300	22656
36*	61.65	8825.6	78	37.86	1773	0	1751	0	0	36	8.16	274	15.52	598	50.65	203	25.67	51	12.75	0	0.00	17.31	67	7200	13700	44700	22656
36*	62.21	8831.2	80	50.72	1743	0	1703	0	0	42	9.51	272	15.40	592	49.60	203	25.49	52	13.00	0	0.00	16.87	54	8400	13600	43800	22512
36*	61.60	8859.6	78	27.96	1771	0	1731	0	0	34	7.68	278	15.69	600	50.79	207	25.84	55	13.75	0	0.00	17.15	66	6800	13900	45000	22896
36*	62.01	8834.8	80	21.76	1771	0	1738	0	0	34	7.70	274	15.51	600	50.93	205	25.86	59	14.75	0	0.00	17.12	63	6800	13700	45000	22848
36*	61.59	8845.6	78	58.59	1769	0	1737	0	0	38	8.59	276	15.60	596	50.19	209	25.61	58	14.50	0	0.00	17.65	60	7600	13800	44400	22656
36*	61.87	8805.6	79	26.74	1784	0	1746	0	0	28	6.36	278	15.79	606	52.13	200	25.73	58	14.50	0	0.00	16.65	66	5600	13900	45900	22656
36*	61.84	8793.2	80	44.60	1763	0	1735	0	0	40	9.10	276	15.69	594	50.15	201	25.06	53	13.25	0	0.00	17.87	67	8000	13800	44100	22032
36*	62.17	8810.8	80	5.58	1740	0	1707	0	0	30	6.81	278	15.78	604	51.75	201	25.66	56	14.00	0	0.00	16.90	57	6000	13900	45600	22608
36*	69.81	8858.4	78	4.34	1783	0	1748	0	0	34	7.68	272	15.35	600	50.80	210	26.17	54	13.50	0	0.00	16.02	62	6800	13600	45000	23184

Table D.4: Results of all runs made with GEANT2 network case 3, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	61.20	9690.0	80	12.18	43	0	43	0	0	20	4.13	678	36.86	338	27.06	282	31.95	106	9.22	0	0.00	17.90	55	4000	35720	26220	30960
1	61.59	9720.4	80	38.08	46	0	46	0	0	20	4.12	676	36.42	342	27.22	286	32.25	103	8.96	0	0.00	17.15	62	4000	35400	26460	31344
1	62.04	9770.8	80	57.11	46	0	46	0	0	24	4.91	660	35.90	338	26.47	285	32.72	92	8.00	0	0.00	17.40	56	4800	35080	25860	31968
1	60.90	9690.4	80	19.39	44	0	44	0	0	18	3.72	664	36.08	344	27.62	284	32.59	105	9.13	0	0.00	18.90	55	3600	34960	26760	31584
1	61.71	9551.6	80	41.15	44	0	44	0	0	24	5.03	660	36.39	338	27.07	279	31.51	96	8.35	0	0.00	18.35	57	4800	34760	25860	30096
1	61.50	9653.6	80	25.07	44	0	44	0	0	18	3.73	672	36.63	344	27.72	276	31.92	100	8.70	0	0.00	16.90	57	3600	35360	26760	30816
1	61.95	9658.4	80	38.47	43	0	43	0	0	30	6.21	652	36.24	332	25.84	286	31.71	98	8.52	0	0.00	16.25	55	6000	35000	24960	30624
1	60.76	9640.4	80	18.88	44	0	44	0	0	20	4.15	676	36.39	342	27.45	278	32.02	95	8.26	0	0.00	17.96	56	4000	35080	26460	30864
1	61.35	9684.8	80	2.61	46	0	46	0	0	20	4.13	674	36.78	342	27.32	277	31.77	98	8.52	0	0.00	16.81	55	4000	35620	26460	30768
1	61.93	9723.6	80	45.30	46	0	46	0	0	22	4.53	674	36.14	340	26.90	285	32.43	104	9.04	0	0.00	17.27	59	4400	35140	26160	31536
12	62.87	9586.8	80	4.68	488	0	488	0	0	20	4.09	688	36.18	342	27.08	274	30.75	104	9.04	0	0.00	17.83	60	4000	35360	26460	30048
12	62.28	9624.8	80	51.57	491	0	491	0	0	18	3.71	698	37.21	340	27.35	271	30.99	108	9.39	0	0.00	18.94	60	3600	36080	26520	30048
12	62.71	9642.0	80	15.96	487	0	487	0	0	26	5.34	662	36.16	336	26.27	277	31.33	105	9.13	0	0.00	17.31	56	5200	35180	25560	30480
12	62.31	9648.0	80	46.66	472	0	472	0	0	24	4.96	662	36.02	338	26.72	282	31.99	97	8.43	0	0.00	18.06	61	4800	34860	25860	30960
12	62.54	9595.6	80	20.92	494	0	494	0	0	18	3.69	662	36.40	344	27.43	267	30.86	88	7.65	0	0.00	16.85	56	3600	35500	26760	30096
12	61.67	9622.8	80	45.85	479	0	479	0	0	18	3.71	678	36.44	344	27.59	276	31.48	100	8.70	0	0.00	17.58	54	3600	35340	26760	30528
12	62.21	9632.4	80	9.47	495	0	495	0	0	14	2.91	690	36.65	348	28.40	281	32.04	95	8.26	0	0.00	17.65	57	2800	35300	27360	30864
12	62.06	9598.0	80	45.76	494	0	494	0	0	22	4.55	670	36.63	340	27.06	272	31.03	115	10.00	0	0.00	16.81	60	4400	35420	26160	30000
12	62.52	9580.0	80	23.93	477	0	477	0	0	20	4.12	654	36.16	342	27.26	267	31.15	101	8.78	0	0.00	17.88	60	4000	35100	26460	30240
12	62.26	9661.2	80	35.69	481	0	481	0	0	16	3.27	666	36.26	342	27.44	278	31.87	98	8.52	0	0.00	16.73	54	3200	35440	26820	31152
36	74.54	9588.0	80	30.00	587	0	587	0	0	20	4.09	672	36.24	338	26.83	273	30.94	99	8.61	0	0.00	16.38	56	4000	35420	26220	30240
36	73.79	9523.2	80	3.87	582	0	582	0	0	20	4.10	658	35.68	342	27.12	276	30.69	97	8.43	0	0.00	17.92	55	4000	34820	26460	29952
36	73.60	9606.4	80	57.99	579	0	579	0	0	20	4.03	666	35.50	342	26.67	273	30.62	102	8.87	0	0.00	16.87	56	4000	35220	26460	30384
36	73.98	9634.8	80	51.12	564	0	563	0	0	22	4.50	670	36.09	340	26.78	279	31.25	101	8.78	0	0.00	17.35	56	4400	35260	26160	30528
36	78.97	9546.8	80	50.03	609	0	609	0	0	22	4.55	670	36.29	340	27.05	270	30.82	93	8.09	0	0.00	17.79	57	4400	35100	26160	29808
36	73.94	9595.2	80	56.69	570	0	570	0	0	24	4.93	670	36.58	338	26.58	272	30.54	91	7.91	0	0.00	17.92	57	4800	35580	25860	29712
36	73.34	9644.4	80	11.09	578	0	578	0	0	18	3.73	658	36.26	344	27.74	276	32.24	95	8.26	0	0.00	16.67	59	3600	34980	26760	31104
36	72.35	9594.8	80	3.14	574	0	574	0	0	20	4.11	664	35.89	342	27.16	273	31.34	93	8.09	0	0.00	18.02	58	4000	34960	26460	30528
36	68.00	9616.8	80	22.26	542	0	541	0	0	16	3.31	658	35.81	346	27.96	276	32.28	90	7.83	0	0.00	17.48	57	3200	34660	27060	31248
36	74.30	9586.8	80	27.53	578	0	578	0	0	20	4.06	688	35.89	342	26.86	274	30.50	104	9.04	0	0.00	17.83	60	4000	35360	26460	30048
36*	64.55	9589.2	80	29.34	481	0	481	0	0	20	4.17	660	36.25	342	27.59	279	31.99	94	8.17	0	0.00	18.48	58	4000	34760	26460	30672
36*	64.02	9621.2	80	1.94	505	0	505	0	0	18	3.74	656	36.81	340	27.56	267	31.88	103	8.96	0	0.00	16.46	56	3600	35420	26520	30672
36*	63.88	9586.8	80	27.97	501	0	501	0	0	20	4.17	688	36.88	342	27.60	274	31.34	104	9.04	0	0.00	17.83	60	4000	35360	26460	30048
36*	63.57	9589.2	80	35.65	503	0	502	0	0	20	4.17	660	36.25	342	27.59	279	31.99	94	8.17	0	0.00	18.48	58	4000	34760	26460	30672
36*	64.52	9622.8	80	42.90	491	0	491	0	0	18	3.74	678	36.73	344	27.81	276	31.72	100	8.70	0	0.00	17.58	54	3600	35340	26760	30528
36*	63.79	9594.8	80	12.18	500	0	500	0	0	18	3.75	674	36.79	344	27.89	269	31.57	110	9.57	0	0.00	18.15	58	3600	35300	26760	30288
36*	63.77	9611.6	80	36.52	495	0	494	0	0	16	3.33	664	36.71	346	28.15	272	31.81	104	9.04	0	0.00	18.37	57	3200	35280	27060	30576
36*	63.54	9588.0	80	29.83	504	0	504	0	0	20	4.17	672	36.94	338	27.35	273	31.54	99	8.61	0	0.00	16.38	56	4000	35420	26220	30240
36*	63.76	9523.2	80	3.74	507	0	507	0	0	20	4.20	658	36.56	342	27.78	276	31.45	97	8.43	0	0.00	17.92	55	4000	34820	26460	29952
36*	64.27	9676.8	80	41.10	504	0	503	0	0	16	3.31	670	36.44	346	27.96	279	32.29	93	8.09	0	0.00	16.12	55	3200	35260	27060	31248

Table D.5: Results of all runs made with GEANT2 network case 4, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	#10G	%10G	#40G	%40G	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	61.53	9353.6	80	53.26	70	0	70	0	0	34	7.27	396	21.17	628	45.29	235	26.27	83	14.43	0	0.00	16.02	60	6800	19800	42360	24576
1	60.87	9348.4	80	1.06	69	0	68	0	0	26	5.56	402	21.50	636	46.60	228	26.34	89	15.48	0	0.00	15.38	48	5200	20100	43560	24624
1	61.37	9353.6	80	21.87	65	0	65	0	0	24	5.13	406	21.70	638	46.89	226	26.27	94	16.35	0	0.00	15.12	57	4800	20300	43860	24576
1	60.82	9378.4	80	4.32	68	0	67	0	0	24	5.12	402	21.60	638	46.77	229	26.51	92	16.00	0	0.00	14.96	61	4800	20260	43860	24864
1	61.60	9352.4	79	14.26	74	0	74	0	0	34	7.27	400	21.62	624	45.04	236	26.07	92	16.00	0	0.00	14.96	55	6800	20220	42120	24384
1	61.37	9281.2	80	50.65	69	0	69	0	0	32	6.90	396	21.33	630	45.96	230	25.81	96	16.70	0	0.00	16.48	57	6400	19800	42660	23952
1	61.32	9378.8	78	24.30	66	0	65	0	0	30	6.40	398	21.39	632	45.81	237	26.41	84	14.61	0	0.00	14.56	56	6000	20060	42960	24768
1	61.07	9291.2	80	42.12	71	0	71	0	0	32	6.89	390	21.16	630	45.91	228	26.04	94	16.35	0	0.00	16.04	56	6400	19660	42660	24192
1	61.17	9342.8	79	37.03	66	0	66	0	0	22	4.71	394	21.26	640	47.27	229	26.77	94	16.35	0	0.00	15.88	61	4400	19860	44160	25008
1	61.26	9316.0	79	12.20	71	0	71	0	0	30	6.44	396	21.43	632	46.11	230	26.02	89	15.48	0	0.00	15.88	49	6000	19960	42960	24240
12	61.62	9240.8	78	48.70	740	0	737	0	0	30	6.41	388	20.72	632	45.88	225	25.68	90	15.65	0	0.00	15.19	57	6000	19400	42960	24048
12	62.26	9327.6	79	58.23	738	0	736	0	0	24	5.13	396	21.14	638	46.84	230	26.50	84	14.61	0	0.00	14.94	54	4800	19800	43860	24816
12	61.31	9302.4	80	12.28	742	0	740	0	0	32	6.84	398	21.45	630	45.62	225	25.56	91	15.83	0	0.00	14.85	58	6400	20060	42660	23904
12	61.85	9299.2	80	44.18	728	0	723	0	0	24	5.14	398	21.29	638	46.93	226	26.14	100	17.39	0	0.00	17.13	57	4800	19900	43860	24432
12	61.04	9286.8	80	43.34	750	0	749	0	0	30	6.40	402	21.44	632	45.82	227	25.39	97	16.87	0	0.00	15.37	61	6000	20100	42960	23808
12	62.18	9291.2	80	36.29	741	0	740	0	0	30	6.46	392	21.26	632	46.23	228	26.03	95	16.52	0	0.00	15.58	58	6000	19760	42960	24192
12	61.43	9292.8	80	22.82	745	0	744	0	0	32	6.89	392	21.33	626	45.65	229	26.14	88	15.30	0	0.00	15.94	56	6400	19820	42420	24288
12	62.17	9275.6	79	40.26	740	0	739	0	0	28	5.96	398	21.60	630	45.82	223	25.41	93	16.17	0	0.00	16.60	65	5600	20280	43020	23856
12	61.81	9313.6	80	20.51	737	0	736	0	0	26	5.56	396	21.17	636	46.57	229	26.28	88	15.30	0	0.00	16.94	62	5200	19800	43560	24576
12	62.93	9300.8	78	30.69	730	0	728	0	0	28	6.00	402	21.54	634	46.37	228	25.77	94	16.35	0	0.00	15.23	60	5600	20100	43260	24048
36	68.27	9251.6	80	44.16	845	0	843	0	0	28	5.98	396	21.15	634	46.20	223	25.48	89	15.48	0	0.00	16.27	57	5600	19800	43260	23856
36	86.81	9256.0	80	47.33	1029	0	1027	0	0	30	6.43	392	21.00	632	46.03	229	25.71	91	15.83	0	0.00	15.35	49	6000	19600	42960	24000
36	67.78	9308.0	80	8.24	810	0	806	0	0	28	5.98	400	21.58	630	45.92	227	25.87	87	15.13	0	0.00	15.38	52	5600	20220	43020	24240
36	73.30	9286.8	79	57.36	885	0	881	0	0	30	6.40	402	21.45	632	45.85	227	25.41	87	15.13	0	0.00	15.85	51	6000	20100	42960	23808
36	74.58	9253.2	80	51.75	905	0	903	0	0	30	6.35	394	21.02	632	45.46	226	25.09	89	15.48	0	0.00	16.12	58	6000	19860	42960	23712
36	85.18	9276.4	79	54.91	1023	0	1018	0	0	28	5.96	400	21.28	634	46.03	225	25.44	99	17.22	0	0.00	15.35	54	5600	20000	43260	23904
36	72.15	9256.8	78	3.26	877	0	872	0	0	30	6.41	396	21.15	632	45.89	227	25.43	100	17.39	0	0.00	15.37	59	6000	19800	42960	23808
36	70.14	9295.6	80	56.69	839	0	836	0	0	32	6.82	396	21.10	630	45.47	230	25.68	89	15.48	0	0.00	15.06	61	6400	19800	42660	24096
36	72.81	9245.6	76	55.35	851	0	848	0	0	32	6.81	402	21.54	630	45.36	220	24.60	99	17.22	0	0.00	15.83	50	6400	20260	42660	23136
36	67.75	9240.8	78	50.56	810	0	805	0	0	30	6.38	388	20.63	632	45.69	225	25.58	90	15.65	0	0.00	15.19	57	6000	19400	42960	24048
36*	62.56	9320.0	79	17.68	756	0	753	0	0	28	6.01	402	21.57	634	46.42	230	26.01	94	16.35	0	0.00	17.15	63	5600	20100	43260	24240
36*	63.76	9285.6	78	4.60	746	0	743	0	0	24	5.17	394	21.39	638	47.23	225	26.21	93	16.17	0	0.00	16.04	51	4800	19860	43860	24336
36*	62.79	9292.8	80	22.40	748	0	743	0	0	32	6.89	392	21.33	626	45.65	229	26.14	88	15.30	0	0.00	15.94	56	6400	19820	42420	24288
36*	63.24	9310.4	77	47.44	741	0	741	0	0	34	7.30	396	21.27	628	45.50	232	25.93	100	17.39	0	0.00	14.65	59	6800	19800	42360	24144
36*	62.51	9321.2	80	12.92	751	0	749	0	0	34	7.30	402	21.56	628	45.44	230	25.70	100	17.39	0	0.00	17.31	56	6800	20100	42360	23952
36*	63.32	9251.6	80	52.92	748	0	741	0	0	28	6.05	396	21.40	634	46.76	223	25.79	89	15.48	0	0.00	16.27	57	5600	19800	43260	23856
36*	63.34	9284.8	80	62.63	748	0	746	0	0	24	5.17	398	21.43	638	47.24	223	26.16	93	16.17	0	0.00	15.92	54	4800	19900	43860	24288
36*	63.48	9285.2	79	47.42	726	0	721	0	0	28	6.03	396	21.32	634	46.59	228	26.05	92	16.00	0	0.00	16.35	61	5600	19800	43260	24192
36*	62.38	9295.6	80	35.12	738	0	735	0	0	24	5.16	404	21.73	638	47.18	221	25.92	97	16.87	0	0.00	15.62	50	4800	20200	43860	24096
36*	63.16	9286.0	79	27.42	753	0	751	0	0	34	7.32	394	21.21	628	45.62	232	25.85	87	15.13	0	0.00	16.56	56	6800	19700	42360	24000

Table D.6: Results of all runs made with GEANT2 network case 5, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	61.43	10233.2	80	22.32	69	0	69	0	0	38	7.43	342	16.93	690	50.83	224	24.81	83	18.04	0	0.00	18.10	62	7600	17320	52020	25392
1	60.92	10227.6	77	51.92	65	0	65	0	0	36	7.04	332	16.60	692	51.16	228	25.20	88	19.13	0	0.00	17.42	61	7200	16980	52320	25776
1	61.04	10253.6	80	44.46	66	0	66	0	0	42	8.19	334	16.29	690	50.38	234	25.14	85	18.48	0	0.00	18.96	67	8400	16700	51660	25776
1	61.65	10270.8	79	19.55	65	0	65	0	0	36	7.01	340	16.77	692	50.94	230	25.28	94	20.43	0	0.00	17.38	60	7200	17220	52320	25968
1	61.01	10249.2	80	31.39	66	0	66	0	0	34	6.63	340	17.02	690	51.11	229	25.24	81	17.61	0	0.00	18.56	62	6800	17440	52380	25872
1	62.07	10250.8	80	26.38	67	0	67	0	0	36	7.02	336	16.60	692	51.04	230	25.33	96	20.87	0	0.00	17.75	68	7200	17020	52320	25968
1	60.76	10322.8	80	9.89	67	0	67	0	0	38	7.36	344	17.09	686	50.16	234	25.39	81	17.61	0	0.00	17.88	67	7600	17640	51780	26208
1	61.32	10266.8	80	7.50	64	0	64	0	0	34	6.62	338	16.83	694	51.25	227	25.29	87	18.91	0	0.00	19.48	59	6800	17280	52620	25968
1	61.00	10293.6	80	17.63	67	0	66	0	0	34	6.61	346	17.23	690	50.89	226	25.27	89	19.35	0	0.00	17.02	61	6800	17740	52380	26016
1	62.04	10281.2	80	46.93	68	0	68	0	0	36	7.00	334	16.24	696	51.12	234	25.63	89	19.35	0	0.00	19.10	63	7200	16700	52560	26352
12	61.96	10214.0	80	8.03	703	0	701	0	0	42	8.20	338	16.72	686	50.22	228	24.61	85	18.48	0	0.00	17.02	62	8400	17120	51420	25200
12	61.26	10241.2	80	7.89	694	0	694	0	0	36	7.01	336	16.57	692	50.94	229	25.19	94	20.43	0	0.00	17.65	62	7200	17020	52320	25872
12	61.98	10252.8	80	58.34	693	0	692	0	0	40	7.76	342	16.79	688	50.15	228	24.71	89	19.35	0	0.00	17.27	66	8000	17320	51720	25488
12	61.68	10216.4	80	38.24	710	0	710	0	0	36	7.00	332	16.34	692	50.84	230	25.09	87	18.91	0	0.00	18.12	60	7200	16820	52320	25824
12	62.13	10252.8	79	25.08	712	0	710	0	0	38	7.37	334	16.19	694	50.67	233	25.18	91	19.78	0	0.00	18.42	66	7600	16700	52260	25968
12	61.64	10216.8	80	40.75	690	0	689	0	0	30	5.82	340	16.70	698	51.62	223	24.95	90	19.57	0	0.00	19.06	65	6000	17220	53220	25728
12	62.07	10234.4	79	3.34	705	0	704	0	0	38	7.38	334	16.64	686	50.28	230	25.08	86	18.70	0	0.00	19.90	68	7600	17140	51780	25824
12	61.74	10251.6	80	24.77	694	0	692	0	0	40	7.80	336	16.60	688	50.45	231	25.14	84	18.26	0	0.00	17.12	66	8000	17020	51720	25776
12	62.24	10190.8	80	4.96	692	0	690	0	0	38	7.42	336	16.39	694	50.99	224	24.64	105	22.83	0	0.00	17.73	60	7600	16800	52260	25248
12	61.35	10247.2	80	23.01	704	0	704	0	0	38	7.38	340	16.73	690	50.53	228	24.90	93	20.22	0	0.00	18.04	61	7600	17220	52020	25632
36	67.97	10250.4	78	33.31	773	0	772	0	0	34	6.57	336	16.45	694	50.86	231	25.19	85	18.48	0	0.00	18.17	57	6800	17020	52620	26064
36	74.35	10171.2	80	1.64	845	0	843	0	0	34	6.57	334	16.56	690	50.61	221	24.54	104	22.61	0	0.00	19.27	60	6800	17140	52380	25392
36	72.87	10185.2	79	53.35	839	0	838	0	0	36	6.99	336	16.67	692	50.78	220	24.41	93	20.22	0	0.00	18.62	56	7200	17180	52320	25152
36	73.27	10226.0	80	53.79	830	0	829	0	0	36	6.97	342	16.98	688	50.43	226	24.63	94	20.43	0	0.00	18.31	64	7200	17540	52080	25440
36	67.24	10226.0	80	3.21	760	0	758	0	0	38	7.42	344	16.78	694	50.99	228	24.59	90	19.57	0	0.00	20.02	60	7600	17200	52260	25200
36	73.51	10210.8	80	41.18	833	0	829	0	0	40	7.74	334	16.59	684	49.83	228	24.67	88	19.13	0	0.00	19.79	62	8000	17140	51480	25488
36	73.88	10221.2	80	11.75	842	0	841	0	0	38	7.33	330	16.12	690	50.14	232	24.94	89	19.35	0	0.00	19.81	66	7600	16720	52020	25872
36	73.27	10227.6	80	7.58	852	0	850	0	0	38	7.34	338	16.54	690	50.26	227	24.67	84	18.26	0	0.00	17.94	64	7600	17120	52020	25536
36	67.02	10198.0	80	52.17	766	0	764	0	0	40	7.74	332	16.27	688	50.02	226	24.60	90	19.57	0	0.00	16.08	59	8000	16820	51720	25440
36	73.62	10211.6	80	42.68	834	0	832	0	0	36	7.01	342	17.08	688	50.70	220	24.63	88	19.13	0	0.00	20.04	58	7200	17540	52080	25296
36*	63.41	10160.0	80	26.63	719	0	718	0	0	40	7.87	324	15.94	692	51.14	229	25.04	91	19.78	0	0.00	19.62	64	8000	16200	51960	25440
36*	62.88	10256.0	80	30.05	719	0	716	0	0	42	8.19	332	16.40	686	50.14	234	25.27	86	18.70	0	0.00	18.04	66	8400	16820	51420	25920
36*	62.46	10250.8	80	4.48	711	0	711	0	0	40	7.80	342	17.11	684	50.22	228	24.86	90	19.57	0	0.00	19.48	62	8000	17540	51480	25488
36*	77.31	10234.4	79	20.12	753	0	753	0	0	38	7.43	334	16.75	686	50.59	230	25.23	86	18.70	0	0.00	19.90	68	7600	17140	51780	25824
36*	62.84	10190.8	80	29.41	718	0	718	0	0	38	7.46	336	16.49	694	51.28	224	24.78	105	22.83	0	0.00	17.73	60	7600	16800	52260	25248
36*	63.23	10156.8	80	36.32	708	0	708	0	0	38	7.48	326	16.21	694	51.45	227	24.86	88	19.13	0	0.00	18.44	64	7600	16460	52260	25248
36*	62.59	10171.2	80	3.09	721	0	720	0	0	34	6.69	334	16.85	690	51.50	221	24.96	104	22.61	0	0.00	19.27	60	6800	17140	52380	25392
36*	63.27	10212.8	80	18.50	709	0	708	0	0	34	6.66	330	16.16	698	51.76	233	25.43	93	20.22	0	0.00	18.98	59	6800	16500	52860	25968
36*	62.70	10247.2	80	5.57	710	0	708	0	0	40	7.81	338	16.71	688	50.47	228	25.01	95	20.65	0	0.00	18.31	64	8000	17120	51720	25632
36*	63.23	10226.0	80	3.31	703	0	699	0	0	38	7.43	344	16.82	694	51.11	228	24.64	90	19.57	0	0.00	20.02	60	7600	17200	52260	25200

Table D.7: Results of all runs made with GEANT2 network case 6, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	63.68	10639.6	80	11.73	30	0	30	0	0	22	4.14	796	38.87	384	28.25	290	28.74	122	9.22	0	0.00	13.92	57	4400	41360	30060	30576
1	61.89	10568.8	80	18.16	30	0	30	0	0	22	4.16	794	39.19	384	28.44	279	28.20	124	9.37	0	0.00	15.38	52	4400	41420	30060	29808
1	62.93	10688.8	80	2.01	32	0	32	0	0	16	2.99	784	38.13	390	28.96	297	29.91	120	9.07	0	0.00	14.02	54	3200	40760	30960	31968
1	62.49	10563.2	80	58.00	33	0	33	0	0	18	3.41	792	38.76	392	29.25	286	28.58	136	10.28	0	0.00	15.75	55	3600	40940	30900	30192
1	61.53	10674.0	80	35.38	32	0	32	0	0	14	2.62	794	38.86	388	29.06	287	29.45	126	9.52	0	0.00	15.15	56	2800	41480	31020	31440
1	60.98	10660.0	80	9.91	33	0	33	0	0	14	2.63	794	38.56	392	29.32	293	29.49	123	9.30	0	0.00	15.44	54	2800	41100	31260	31440
1	61.98	10666.4	80	35.58	31	0	31	0	0	20	3.75	796	38.63	386	28.46	294	29.16	122	9.22	0	0.00	15.42	53	4000	41200	30360	31104
1	61.99	10671.6	80	31.25	32	0	32	0	0	16	3.00	796	39.11	386	28.79	289	29.10	123	9.30	0	0.00	15.69	56	3200	41740	30720	31056
1	61.45	10624.4	80	43.85	30	0	30	0	0	14	2.64	788	38.44	400	29.87	284	29.05	114	8.62	0	0.00	16.35	55	2800	40840	31740	30864
1	62.15	10635.2	80	11.78	32	0	32	0	0	18	3.39	792	38.49	392	29.05	289	29.07	113	8.54	0	0.00	14.50	56	3600	40940	30900	30912
12	63.65	10550.4	80	19.47	325	0	324	0	0	16	3.01	792	38.36	398	29.62	281	28.40	125	9.45	0	0.00	15.19	55	3200	40720	31440	30144
12	63.71	10560.8	80	47.72	333	0	333	0	0	16	2.99	776	38.00	390	28.92	283	28.74	114	8.62	0	0.00	16.06	53	3200	40680	30960	30768
12	62.45	10580.8	80	40.14	332	0	332	0	0	16	2.99	794	38.25	394	29.19	282	28.57	129	9.75	0	0.00	14.10	54	3200	40880	31200	30528
12	63.62	10556.8	80	4.77	323	0	323	0	0	18	3.37	786	38.45	388	28.74	281	28.39	127	9.60	0	0.00	15.08	53	3600	41020	30660	30288
12	63.29	10611.6	80	25.85	317	0	316	0	0	16	3.00	798	38.59	390	29.04	288	28.91	129	9.75	0	0.00	14.92	58	3200	41140	30960	30816
12	63.26	10574.8	80	44.01	321	0	320	0	0	14	2.61	798	38.15	396	29.37	285	28.46	114	8.62	0	0.00	16.44	54	2800	40920	31500	30528
12	62.93	10569.2	80	31.42	315	0	315	0	0	14	2.64	796	38.78	392	29.42	281	28.64	128	9.67	0	0.00	14.60	53	2800	41200	31260	30432
12	63.40	10541.6	80	23.37	319	0	318	0	0	16	2.98	782	37.66	394	29.05	284	28.47	115	8.69	0	0.00	15.67	57	3200	40440	31200	30576
12	63.32	10629.6	80	55.68	333	0	331	0	0	14	2.62	800	38.12	396	29.50	293	29.31	118	8.92	0	0.00	14.73	60	2800	40700	31500	31296
12	63.12	10501.6	80	11.83	327	0	327	0	0	14	2.62	774	37.59	400	29.72	280	28.41	121	9.15	0	0.00	15.65	52	2800	40140	31740	30336
36	76.46	10558.0	80	12.45	408	0	407	0	0	16	2.97	778	38.05	390	28.78	280	28.33	136	10.28	0	0.00	16.19	57	3200	40940	30960	30480
36	69.39	10569.2	80	35.43	361	0	361	0	0	18	3.35	794	38.57	384	28.28	283	28.07	116	8.77	0	0.00	15.56	55	3600	41480	30420	30192
36	73.96	10601.2	80	2.61	389	0	389	0	0	12	2.22	796	37.60	398	29.41	287	28.81	116	8.77	0	0.00	14.19	59	2400	40660	31800	31152
36	73.40	10590.0	80	18.99	385	0	384	0	0	18	3.34	782	37.47	392	28.63	291	28.69	121	9.15	0	0.00	16.31	55	3600	40440	30900	30960
36	74.16	10568.8	79	52.17	383	0	382	0	0	14	2.59	786	38.30	392	28.96	275	28.06	109	8.24	0	0.00	14.13	51	2800	41340	31260	30288
36	78.90	10504.8	80	55.44	406	0	406	0	0	18	3.36	790	38.08	388	28.66	283	28.08	119	8.99	0	0.00	16.67	56	3600	40740	30660	30048
36	73.07	10568.8	80	66.47	384	0	384	0	0	22	4.07	794	38.32	384	27.81	279	27.57	124	9.37	0	0.00	15.38	52	4400	41420	30060	29808
36	73.71	10522.4	80	58.73	377	0	377	0	0	18	3.34	782	37.92	388	28.48	281	28.00	134	10.13	0	0.00	14.19	59	3600	40820	30660	30144
36	73.38	10560.0	80	28.70	377	0	377	0	0	16	2.98	792	37.44	398	29.25	290	28.58	123	9.30	0	0.00	15.96	56	3200	40240	31440	30720
36	79.81	10580.0	79	53.81	393	0	393	0	0	20	3.77	788	38.57	386	28.59	286	28.70	124	9.37	0	0.00	13.27	57	4000	40960	30360	30480
36*	65.52	10556.8	80	27.35	339	0	339	0	0	18	3.41	786	38.86	388	29.04	281	28.69	127	9.60	0	0.00	15.08	53	3600	41020	30660	30288
36*	64.47	10574.8	80	44.73	337	0	337	0	0	14	2.65	798	38.70	396	29.79	285	28.87	114	8.62	0	0.00	16.44	54	2800	40920	31500	30528
36*	65.93	10578.0	80	20.34	334	0	333	0	0	18	3.40	786	38.57	392	29.21	286	28.81	118	8.92	0	0.00	15.56	57	3600	40800	30900	30480
36*	64.62	10573.2	80	20.48	340	0	340	0	0	16	3.03	790	38.68	390	29.28	288	29.01	112	8.47	0	0.00	14.54	55	3200	40900	30960	30672
36*	65.44	10501.6	80	63.82	335	0	334	0	0	14	2.67	774	38.22	400	30.22	280	28.89	121	9.15	0	0.00	15.65	52	2800	40140	31740	30336
36*	65.68	10552.8	80	27.74	357	0	357	0	0	16	3.03	780	38.02	398	29.79	286	29.16	109	8.24	0	0.00	16.38	55	3200	40120	31440	30768
36*	65.15	10552.4	80	55.21	345	0	345	0	0	18	3.41	792	38.29	396	29.51	288	28.79	117	8.84	0	0.00	15.00	58	3600	40400	31140	30384
36*	65.66	10546.8	80	35.13	342	0	342	0	0	14	2.65	776	37.85	400	30.09	287	29.40	123	9.30	0	0.00	14.23	55	2800	39920	31740	31008
36*	66.25	10562.8	80	51.20	346	0	345	0	0	18	3.41	788	38.21	396	29.48	285	28.90	127	9.60	0	0.00	12.75	54	3600	40360	31140	30528
36*	64.27	10471.2	80	36.66	340	0	340	0	0	20	3.82	780	38.58	386	28.99	282	28.60	134	10.13	0	0.00	15.54	53	4000	40400	30360	29952

Table D.8: Results of all runs made with GEANT2 network case 7, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	62.07	11074.4	78	42.42	30	0	30	0	0	34	6.14	482	22.16	722	44.48	287	27.22	136	20.54	0	0.00	15.04	57	6800	24540	49260	30144
1	61.84	11182.8	80	2.39	28	0	28	0	0	36	6.44	490	22.70	712	43.35	295	27.51	141	21.30	0	0.00	16.83	49	7200	25380	48480	30768
1	62.46	10975.2	80	42.18	29	0	29	0	0	34	6.20	472	21.85	726	45.10	280	26.85	127	19.18	0	0.00	16.98	68	6800	23980	49500	29472
1	61.34	11032.0	79	19.48	29	0	29	0	0	36	6.53	480	21.90	728	44.82	285	26.76	136	20.54	0	0.00	17.79	54	7200	24160	49440	29520
1	62.67	11120.0	80	20.98	29	0	29	0	0	38	6.83	472	21.56	722	43.97	296	27.63	135	20.39	0	0.00	16.40	52	7600	23980	48900	30720
1	61.95	11087.2	79	35.90	28	0	28	0	0	30	5.41	478	21.95	726	44.97	291	27.66	130	19.64	0	0.00	15.02	51	6000	24340	49860	30672
1	61.57	11084.4	80	57.10	31	0	31	0	0	32	5.77	478	22.10	724	44.71	288	27.41	129	19.49	0	0.00	15.88	66	6400	24500	49560	30384
1	62.85	11096.4	80	6.15	30	0	30	0	0	38	6.85	482	21.92	722	44.07	293	27.17	135	20.39	0	0.00	15.75	66	7600	24320	48900	30144
1	62.07	11046.0	80	51.09	31	0	31	0	0	36	6.52	464	21.35	724	44.54	292	27.59	123	18.58	0	0.00	16.90	66	7200	23580	49200	30480
1	62.96	11038.0	80	46.78	28	0	28	0	0	38	6.89	478	21.85	722	44.30	289	26.96	131	19.79	0	0.00	16.12	52	7600	24120	48900	29760
12	63.69	11033.2	80	9.30	279	0	279	0	0	36	6.51	470	21.23	728	44.67	289	27.28	131	19.79	0	0.00	17.79	52	7200	23500	49440	30192
12	62.46	10998.0	80	58.72	284	0	284	0	0	32	5.78	468	21.46	728	44.94	287	27.07	129	19.49	0	0.00	17.23	70	6400	23780	49800	30000
12	63.88	11007.2	80	27.78	283	0	282	0	0	36	6.47	472	21.74	720	43.99	284	26.70	126	19.03	0	0.00	16.08	51	7200	24200	48960	29712
12	62.71	10980.4	80	17.85	281	0	281	0	0	32	5.79	474	21.43	732	45.24	282	26.82	128	19.34	0	0.00	16.87	50	6400	23700	50040	29664
12	63.30	10946.0	80	35.40	282	0	282	0	0	38	6.82	464	20.83	726	44.12	285	26.50	121	18.28	0	0.00	18.56	67	7600	23200	49140	29520
12	63.27	10994.0	80	28.13	266	0	266	0	0	32	5.78	480	21.89	728	45.00	282	26.68	133	20.09	0	0.00	15.73	52	6400	24220	49800	29520
12	63.06	11004.0	80	50.82	282	0	282	0	0	34	6.18	470	21.36	730	45.20	287	27.26	124	18.73	0	0.00	17.44	66	6800	23500	49740	30000
12	63.35	11026.4	80	37.82	283	0	283	0	0	38	6.87	474	21.58	726	44.44	285	26.82	130	19.64	0	0.00	15.83	56	7600	23860	49140	29664
12	63.32	10992.8	80	57.00	284	0	284	0	0	34	6.09	472	21.33	726	44.33	285	26.69	136	20.54	0	0.00	18.73	67	6800	23820	49500	29808
12	62.95	10905.6	80	49.06	286	0	286	0	0	40	7.21	472	21.65	716	43.56	279	25.81	117	17.67	0	0.00	16.10	55	8000	24040	48360	28656
36	78.23	10977.2	79	14.51	347	0	347	0	0	34	6.10	472	21.32	730	44.64	280	26.45	128	19.34	0	0.00	17.63	51	6800	23760	49740	29472
36	74.19	10994.0	78	61.34	335	0	335	0	0	28	5.02	474	21.23	736	45.37	284	26.88	135	20.39	0	0.00	16.06	52	5600	23700	50640	30000
36	72.68	11034.4	79	19.72	323	0	323	0	0	36	6.43	468	21.03	728	44.14	290	26.91	126	19.03	0	0.00	16.44	47	7200	23560	49440	30144
36	73.76	10954.8	80	54.85	333	0	333	0	0	30	5.30	474	21.52	722	43.84	278	26.13	129	19.49	0	0.00	17.40	56	6000	24360	49620	29568
36	77.91	10996.0	80	53.81	343	0	343	0	0	38	6.83	470	21.52	718	43.74	286	26.75	126	19.03	0	0.00	17.81	56	7600	23940	48660	29760
36	74.97	11004.8	80	60.36	339	0	339	0	0	30	5.43	462	21.20	734	45.56	284	27.41	123	18.58	0	0.00	17.60	58	6000	23420	50340	30288
36	72.93	10967.2	80	58.34	327	0	327	0	0	38	6.80	474	21.20	726	43.96	282	26.15	122	18.43	0	0.00	18.13	54	7600	23700	49140	29232
36	74.30	10933.6	80	24.07	331	0	331	0	0	38	6.75	476	21.46	722	43.40	276	25.43	125	18.88	0	0.00	17.63	64	7600	24180	48900	28656
36	79.42	11014.8	80	45.82	356	0	356	0	0	36	6.43	484	21.81	724	43.93	280	26.19	130	19.64	0	0.00	15.63	57	7200	24420	49200	29328
36	74.07	11011.6	80	38.81	325	0	325	0	0	32	5.67	474	21.53	724	43.92	284	26.46	124	18.73	0	0.00	16.92	56	6400	24300	49560	29856
36*	65.50	10980.4	80	19.00	290	0	290	0	0	32	5.83	474	21.58	732	45.57	282	27.02	128	19.34	0	0.00	16.87	50	6400	23700	50040	29664
36*	65.35	11034.0	80	47.81	291	0	291	0	0	40	7.25	472	21.73	720	44.05	292	26.97	123	18.58	0	0.00	17.50	51	8000	23980	48600	29760
36*	66.30	10975.2	80	50.47	296	0	296	0	0	34	6.20	480	22.07	726	45.10	282	26.63	117	17.67	0	0.00	17.38	54	6800	24220	49500	29232
36*	77.91	10992.8	80	56.80	312	0	312	0	0	34	6.19	472	21.67	726	45.03	285	27.12	136	20.54	0	0.00	18.73	67	6800	23820	49500	29808
36*	65.79	10987.2	80	3.43	290	0	290	0	0	34	6.19	482	21.93	730	45.27	279	26.61	136	20.54	0	0.00	18.98	64	6800	24100	49740	29232
36*	65.05	10962.8	80	60.26	286	0	286	0	0	36	6.57	470	21.58	728	45.10	283	26.75	121	18.28	0	0.00	18.13	64	7200	23660	49440	29328
36*	65.47	10994.0	78	49.73	294	0	294	0	0	28	5.09	474	21.56	736	46.06	284	27.29	135	20.39	0	0.00	16.06	52	5600	23700	50640	30000
36*	66.25	11034.4	79	19.06	293	0	293	0	0	36	6.53	468	21.35	728	44.81	290	27.32	126	19.03	0	0.00	16.44	47	7200	23560	49440	30144
36*	69.34	11036.4	80	50.06	298	0	298	0	0	36	6.52	478	22.45	712	43.93	286	27.10	133	20.09	0	0.00	15.37	51	7200	24780	48480	29904
36*	65.15	11008.8	79	14.38	282	0	282	0	0	36	6.54	470	21.69	724	44.69	285	27.08	121	18.28	0	0.00	17.35	50	7200	23880	49200	29808

Table D.9: Results of all runs made with GEANT2 network case 8, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	61.95	12833.6	80	48.17	32	0	32	0	0	42	6.55	406	16.29	794	46.80	340	30.37	116	21.93	0	0.00	14.77	54	8400	20900	60060	38976
1	61.16	12727.2	80	10.73	30	0	30	0	0	44	6.91	418	16.94	788	46.77	328	29.38	117	22.12	0	0.00	15.31	51	8800	21560	59520	37392
1	62.00	12635.2	80	28.55	31	0	31	0	0	44	6.96	396	16.15	792	47.30	334	29.59	114	21.55	0	0.00	14.17	55	8800	20400	59760	37392
1	60.98	12735.6	80	9.25	32	0	32	0	0	48	7.54	402	16.72	780	46.08	335	29.66	123	23.25	0	0.00	14.94	57	9600	21300	58680	37776
1	62.02	12794.0	80	53.44	32	0	32	0	0	42	6.57	414	17.04	782	46.38	334	30.01	122	23.06	0	0.00	14.96	53	8400	21800	59340	38400
1	61.96	12694.4	80	4.67	33	0	33	0	0	44	6.93	404	16.39	792	47.08	333	29.61	120	22.68	0	0.00	15.31	53	8800	20800	59760	37584
1	61.96	12811.6	80	11.14	33	0	33	0	0	44	6.87	410	16.81	784	46.27	341	30.05	108	20.42	0	0.00	15.08	60	8800	21540	59280	38496
1	61.76	12895.6	80	15.94	34	0	34	0	0	48	7.44	402	15.71	796	46.25	360	30.60	110	20.79	0	0.00	15.69	51	9600	20260	59640	39456
1	61.23	12770.4	80	25.49	33	0	33	0	0	46	7.20	396	15.68	794	46.75	350	30.37	117	22.12	0	0.00	14.98	54	9200	20020	59700	38784
1	60.64	12614.4	80	19.41	33	0	33	0	0	48	7.61	392	15.89	788	46.90	338	29.60	109	20.60	0	0.00	15.04	53	9600	20040	59160	37344
12	62.93	12634.4	80	7.68	332	0	332	0	0	50	7.78	406	16.60	778	45.42	329	28.50	135	25.52	0	0.00	14.71	58	10000	21340	58380	36624
12	62.87	12672.8	80	3.03	323	0	323	0	0	48	7.48	410	17.64	760	44.79	321	28.84	112	21.17	0	0.00	15.50	59	9600	22640	57480	37008
12	62.81	12650.4	80	24.57	325	0	325	0	0	46	7.19	412	17.34	778	45.92	325	28.44	118	22.31	0	0.00	16.02	55	9200	22180	58740	36384
12	63.35	12680.0	80	51.07	331	0	331	0	0	50	7.86	398	16.11	786	46.26	342	29.43	115	21.74	0	0.00	14.21	57	10000	20500	58860	37440
12	62.65	12714.0	80	51.70	330	0	330	0	0	50	7.85	406	16.93	774	45.64	339	29.39	112	21.17	0	0.00	14.15	61	10000	21560	58140	37440
12	62.49	12459.6	80	26.83	330	0	330	0	0	48	7.48	398	16.31	780	45.70	316	27.55	113	21.36	0	0.00	15.02	57	9600	20940	58680	35376
12	63.07	12703.2	80	45.60	326	0	326	0	0	40	6.25	404	16.24	796	47.12	336	29.57	117	22.12	0	0.00	14.21	57	8000	20800	60360	37872
12	62.56	12554.4	80	28.84	335	0	335	0	0	44	6.92	398	15.82	796	47.16	326	28.79	124	23.44	0	0.00	13.40	53	8800	20120	60000	36624
12	63.91	12617.2	80	23.43	325	0	325	0	0	44	6.88	402	16.19	792	46.75	329	28.88	111	20.98	0	0.00	14.67	54	8800	20700	59760	36912
12	62.48	12660.4	80	44.65	314	0	314	0	0	44	6.93	404	16.69	788	46.89	325	29.23	117	22.12	0	0.00	14.60	58	8800	21180	59520	37104
36	79.40	12618.4	80	48.50	406	0	406	0	0	50	7.79	398	16.31	778	45.46	333	28.71	118	22.31	0	0.00	15.27	54	10000	20940	58380	36864
36	74.61	12556.0	80	8.36	382	0	382	1	0	44	6.81	406	15.87	796	46.41	322	28.03	115	21.74	0	0.00	14.10	50	8800	20520	60000	36240
36	74.85	12725.6	80	31.87	387	0	387	0	0	50	7.76	404	16.19	782	45.51	335	29.33	124	23.44	0	0.00	14.02	51	10000	20860	58620	37776
36	78.76	12647.2	80	35.51	406	0	406	0	0	48	7.54	410	17.09	776	45.89	322	28.80	119	22.50	0	0.00	14.62	57	9600	21760	58440	36672
36	73.65	12660.4	80	53.98	382	0	382	0	0	48	7.38	406	15.94	788	45.47	334	28.52	113	21.36	0	0.00	13.33	59	9600	20740	59160	37104
36	74.52	12561.6	80	57.03	380	0	380	0	0	44	6.76	400	16.28	784	45.53	323	27.91	122	23.06	0	0.00	15.63	56	8800	21200	59280	36336
36	116.49	12660.8	80	55.29	544	0	544	0	0	48	7.55	408	16.38	788	46.51	330	29.09	120	22.68	0	0.00	13.92	48	9600	20840	59160	37008
36	73.30	12642.4	80	11.87	379	0	379	0	0	46	7.16	396	15.70	794	46.46	332	29.06	117	22.12	0	0.00	13.21	55	9200	20180	59700	37344
36	73.04	12676.8	80	24.01	385	0	385	1	0	42	6.54	404	16.03	798	46.97	332	29.20	119	22.50	0	0.00	14.40	49	8400	20580	60300	37488
36	74.22	12675.6	80	29.56	370	0	370	0	0	42	6.62	404	16.75	786	46.98	334	29.60	114	21.55	0	0.00	14.29	56	8400	21240	59580	37536
36*	65.30	12696.8	80	27.43	338	0	338	0	0	46	7.25	406	17.15	774	46.07	338	29.53	109	20.60	0	0.00	14.44	57	9200	21780	58500	37488
36*	65.18	12597.6	80	64.35	343	0	343	0	0	50	7.94	402	16.30	786	46.72	330	29.03	122	23.06	0	0.00	15.12	53	10000	20540	58860	36576
36*	65.99	12676.8	80	13.48	340	0	340	0	0	48	7.57	406	16.19	792	46.86	337	29.38	110	20.79	0	0.00	14.12	57	9600	20520	59400	37248
36*	65.22	12677.6	80	5.35	335	0	335	0	0	48	7.57	406	16.53	784	46.48	333	29.42	132	24.95	0	0.00	14.69	57	9600	20960	58920	37296
36*	65.85	12556.0	80	8.89	338	0	338	1	0	44	7.01	406	16.34	796	47.79	322	28.86	115	21.74	0	0.00	14.10	50	8800	20520	60000	36240
36*	65.71	12651.6	80	29.13	335	0	335	0	0	46	7.27	412	16.63	790	47.00	331	29.10	112	21.17	0	0.00	14.21	56	9200	21040	59460	36816
36*	65.61	12647.2	80	44.57	330	0	330	0	0	48	7.59	410	17.21	776	46.21	322	29.00	119	22.50	0	0.00	14.62	57	9600	21760	58440	36672
36*	65.55	12678.0	80	35.21	332	0	332	0	0	46	7.26	402	16.50	786	46.71	336	29.53	105	19.85	0	0.00	13.69	54	9200	20920	59220	37440
36*	65.64	12553.6	80	9.41	333	0	333	0	0	50	7.97	410	17.16	778	46.50	326	28.37	123	23.25	0	0.00	15.19	55	10000	21540	58380	35616
36*	64.99	12622.8	80	23.00	335	0	335	0	0	46	7.29	412	16.67	790	47.11	331	28.94	111	20.98	0	0.00	14.52	51	9200	21040	59460	36528

Table D.10: Results of all runs made with GEANT2 network case 9, in 60 seconds.

D.2 GEANT2, Given 300 Seconds

Symbol	Name
$\#T$	Number of Threads
t_E	Time of Execution
C	Best Cost Solution found
CA	Highest Channel Assigned
t_{sol}	Found Solution Time
$\#i$	Number of Iterations
$\#IS$	Number of Invalid Solutions
$\#G_U$	Number of Greedy Solutions Unfeasible
$\#LS_U$	Number of Local Search Solutions Unfeasible
UD	Unfeasible Degree
$\#IM$	Number of Invert Multiplex used
C_{IM}	Cost % of Invert Multiplex
$\#MX$	Number of Muxponders placed
C_{MX}	Cost % of Muxponders
$\#TX$	Number of Transponders placed
C_{TX}	Cost % of Transponders
$\#3R$	Number of $3R$ regenerators placed
C_{3R}	Cost % of $3R$ regenerators
#10	Number of Multi-Hop Grooming of $10Gb/s$
%10	Traffic % of Multi-Hop Grooming of $10Gb/s$
#40	Number of Multi-hop Grooming of $40Gb/s$
%40	Traffic % of Multi-hop Grooming of $40Gb/s$
$\bar{m}F$	Average Fragmentation at Channel Assigned
MF	Max Fragmentation at Channel Assigned
C_{IM}	Cost of Invert Multiplexers
C_{MX}	Cost of Multiplexers
C_{TX}	Cost of Transponders
C_{3R}	Cost of $3R$ regenerators

Table D.11: Header symbols and their description.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	#10G	%10G	#40G	%40G	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.92	7714.8	63	122.04	772	0	0	0	0	12	3.11	524	37.49	302	30.72	199	28.68	56	5.60	0	0.00	13.58	44	2400	28920	23700	22128
1	301.33	7703.2	63	151.10	768	0	0	0	0	16	4.15	526	37.88	298	29.99	196	27.98	59	5.90	0	0.00	12.65	42	3200	29180	23100	21552
1	300.58	7732.4	67	138.70	781	0	0	0	0	16	4.14	536	37.56	298	29.87	202	28.43	56	5.60	0	0.00	12.58	46	3200	29040	23100	21984
1	300.85	7714.4	61	174.22	769	0	0	0	0	12	3.11	538	37.98	302	30.72	198	28.19	64	6.40	0	0.00	11.67	46	2400	29300	23700	21744
1	300.64	7711.6	61	156.72	771	0	0	0	0	14	3.63	530	37.89	300	30.34	193	28.13	56	5.60	0	0.00	12.23	42	2800	29220	23400	21696
1	301.24	7728.8	62	251.36	770	0	0	0	0	16	4.14	534	37.65	298	29.89	201	28.32	55	5.50	0	0.00	12.40	44	3200	29100	23100	21888
1	300.44	7684.0	64	264.47	776	0	0	0	0	16	4.16	542	37.98	298	30.06	197	27.80	61	6.10	0	0.00	14.15	47	3200	29180	23100	21360
1	301.16	7733.2	62	41.23	766	0	0	0	0	12	3.10	536	37.76	302	30.65	198	28.49	60	6.00	0	0.00	12.08	44	2400	29200	23700	22032
1	301.17	7720.4	67	204.98	779	0	0	0	0	16	4.14	524	37.46	298	29.92	205	28.48	52	5.20	0	0.00	13.17	47	3200	28920	23100	21984
1	300.49	7716.4	65	50.67	777	0	0	0	0	14	3.63	538	38.18	300	30.33	194	27.87	61	6.10	0	0.00	13.31	47	2800	29460	23400	21504
12	301.10	7666.0	63	55.29	7796	0	0	0	0	14	3.63	534	37.74	300	30.34	194	27.70	67	6.70	0	0.00	13.83	45	2800	29100	23400	21360
12	301.14	7677.2	61	213.39	7912	0	0	0	0	12	3.11	536	37.46	302	30.74	197	28.27	50	5.00	0	0.00	13.17	41	2400	28880	23700	21792
12	301.39	7679.2	67	50.67	7918	0	0	0	0	18	4.69	532	37.56	296	29.69	199	28.07	56	5.60	0	0.00	13.48	49	3600	28840	22800	21552
12	300.96	7684.0	63	176.45	7341	0	0	0	0	18	4.69	532	37.53	296	29.67	201	28.11	62	6.20	0	0.00	12.87	46	3600	28840	22800	21600
12	301.16	7617.2	64	37.61	8218	0	0	0	0	16	4.17	528	37.55	298	30.12	194	27.48	64	6.40	0	0.00	13.65	45	3200	28800	23100	21072
12	300.88	7690.0	65	25.07	8263	0	0	0	0	16	4.15	524	37.27	298	29.93	199	28.30	54	5.40	0	0.00	13.25	44	3200	28760	23100	21840
12	301.33	7672.0	63	279.72	8305	0	1	0	0	16	4.16	530	37.82	298	30.06	197	27.80	54	5.40	0	0.00	11.92	43	3200	29060	23100	21360
12	300.88	7661.2	67	162.57	8212	0	0	0	0	16	4.16	540	37.38	298	30.03	199	28.01	51	5.10	0	0.00	13.88	48	3200	28760	23100	21552
12	301.22	7666.4	63	131.26	8248	0	0	0	0	16	4.14	526	37.37	298	29.91	197	27.85	58	5.80	0	0.00	14.92	43	3200	28860	23100	21504
12	300.96	7676.8	62	15.99	7561	0	0	0	0	18	4.66	520	37.83	296	29.54	192	27.42	54	5.40	0	0.00	12.88	43	3600	29200	22800	21168
36	307.77	7687.6	64	292.38	8523	0	0	0	0	10	2.59	526	37.20	304	31.11	198	28.75	55	5.50	0	0.00	12.71	46	2000	28700	24000	22176
36	313.75	7678.0	63	111.35	8275	0	0	0	0	10	2.60	526	37.29	304	31.18	197	28.69	60	6.00	0	0.00	12.65	45	2000	28700	24000	22080
36	313.26	7686.8	63	227.03	8452	0	0	0	0	12	3.12	536	38.20	302	30.83	193	27.85	53	5.30	0	0.00	13.56	49	2400	29360	23700	21408
36	313.65	7680.8	66	299.93	8766	0	0	0	0	16	4.14	534	37.66	298	29.89	196	27.70	64	6.40	0	0.00	13.87	47	3200	29100	23100	21408
36	313.14	7673.2	65	89.95	8637	0	0	0	0	18	4.65	550	37.78	296	29.44	197	27.21	58	5.80	0	0.00	13.88	45	3600	29260	22800	21072
36	314.14	7698.0	65	149.57	8419	0	0	0	0	14	3.62	542	37.73	300	30.26	198	27.93	64	6.40	0	0.00	12.81	47	2800	29180	23400	21600
36	315.85	7673.6	63	195.98	8467	0	0	0	0	14	3.63	532	37.39	300	30.33	193	28.13	60	6.00	0	0.00	11.77	46	2800	28840	23400	21696
36	313.01	7617.2	64	160.27	8199	0	0	0	0	16	4.13	528	37.21	298	29.84	194	27.22	64	6.40	0	0.00	13.65	45	3200	28800	23100	21072
36	314.14	7690.0	65	137.69	8800	0	0	0	0	16	4.15	524	37.26	298	29.93	199	28.29	54	5.40	0	0.00	13.25	44	3200	28760	23100	21840
36	312.03	7660.8	64	4.12	8721	0	0	0	0	16	4.15	530	37.44	298	29.92	196	27.73	61	6.10	0	0.00	13.62	45	3200	28900	23100	21408
36*	302.03	7666.8	64	100.91	8457	0	0	0	0	14	3.65	522	37.59	300	30.52	194	28.24	57	5.70	0	0.00	13.31	44	2800	28820	23400	21648
36*	302.13	7678.4	61	93.27	8390	0	0	0	0	14	3.65	524	37.87	300	30.48	194	28.01	56	5.60	0	0.00	11.94	43	2800	29080	23400	21504
36*	301.98	7693.6	66	225.65	8229	0	0	0	0	10	2.60	532	37.69	304	31.19	197	28.51	61	6.10	0	0.00	12.58	47	2000	29000	24000	21936
36*	301.72	7588.0	63	43.13	7984	0	0	0	0	14	3.69	536	38.27	300	30.84	188	27.20	59	5.90	0	0.00	13.46	46	2800	29040	23400	20640
36*	301.72	7668.8	64	88.66	8437	0	0	0	0	16	4.17	538	37.79	298	30.12	199	27.92	57	5.70	0	0.00	12.85	46	3200	28980	23100	21408
36*	301.92	7679.2	64	180.21	8448	0	0	0	0	14	3.65	536	37.82	300	30.47	199	28.07	54	5.40	0	0.00	13.63	46	2800	29040	23400	21552
36*	301.70	7690.0	65	98.72	8308	0	0	0	0	16	4.16	524	37.40	298	30.04	199	28.40	54	5.40	0	0.00	13.25	44	3200	28760	23100	21840
36*	301.70	7638.8	66	281.19	8451	0	0	0	0	14	3.67	534	37.68	300	30.63	196	28.03	55	5.50	0	0.00	13.40	47	2800	28780	23400	21408
36*	317.27	7660.8	64	20.08	7531	0	0	0	0	16	4.18	530	37.72	298	30.15	196	27.94	61	6.10	0	0.00	13.62	45	3200	28900	23100	21408
36*	301.84	7671.2	63	114.55	8331	0	0	0	0	14	3.65	552	38.06	300	30.50	195	27.78	61	6.10	0	0.00	12.58	46	2800	29200	23400	21312

Table D.12: Results of all runs made with GEANT2 network case 1, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
#T	t_E	C	CA	t_{sol}	#i	#IS	$\#G_U$	$\#LS_U$	UD	#IM	C_{IM}	#MX	C_{MX}	#TX	C_{TX}	#3R	C_{3R}	#10G	%10G	#40G	%40G	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.66	7959.2	79	280.88	795	0	597	0	0	10	2.51	324	20.35	564	49.75	203	27.38	48	9.60	0	0.00	19.38	60	2000	16200	39600	21792
1	300.63	7967.2	78	142.54	789	0	609	0	0	10	2.51	316	19.83	564	49.70	208	27.95	56	11.20	0	0.00	18.23	62	2000	15800	39600	22272
1	300.97	7985.6	79	48.75	816	0	610	0	0	14	3.51	326	21.24	550	48.09	205	27.17	56	11.20	0	0.00	18.00	64	2800	16960	38400	21696
1	300.47	8002.4	79	12.51	800	0	580	0	0	12	3.00	316	20.42	558	48.81	206	27.77	59	11.80	0	0.00	17.73	62	2400	16340	39060	22224
1	301.02	7972.4	80	167.42	804	0	632	0	0	12	3.01	326	20.72	558	48.99	207	27.27	53	10.60	0	0.00	18.27	64	2400	16520	39060	21744
1	300.52	7962.4	77	103.47	814	0	638	0	0	12	3.01	324	20.62	558	49.06	207	27.31	50	10.00	0	0.00	16.08	61	2400	16420	39060	21744
1	300.75	8020.0	78	2.46	797	0	602	0	0	6	1.50	322	20.55	564	49.83	205	28.13	57	11.40	0	0.00	18.35	61	1200	16480	39960	22560
1	301.10	7989.2	80	133.80	793	0	628	0	0	16	4.01	318	20.58	554	48.14	206	27.28	53	10.60	0	0.00	18.23	65	3200	16440	38460	21792
1	300.46	7999.2	77	225.03	796	0	610	0	0	12	3.00	322	20.33	562	49.13	207	27.54	58	11.60	0	0.00	16.75	55	2400	16260	39300	22032
1	300.94	8006.8	76	59.42	799	0	602	0	0	6	1.50	322	20.66	560	49.61	207	28.24	43	8.60	0	0.00	17.58	59	1200	16540	39720	22608
12	301.70	7946.4	78	52.15	8269	0	6305	0	0	12	3.01	330	20.67	562	49.23	202	26.63	53	10.60	0	0.00	17.46	57	2400	16500	39300	21264
12	300.77	7971.2	80	188.04	8656	0	6623	0	0	12	3.01	320	20.31	558	48.91	207	27.59	50	10.00	0	0.00	18.21	58	2400	16220	39060	22032
12	301.20	7952.8	78	212.39	8530	0	6512	0	0	10	2.50	326	20.66	560	49.22	203	27.07	52	10.40	0	0.00	18.85	60	2000	16520	39360	21648
12	301.20	7933.2	78	74.29	8429	0	6416	0	0	10	2.51	316	21.04	554	48.91	199	27.03	51	10.20	0	0.00	17.06	61	2000	16780	39000	21552
12	300.83	7949.6	80	87.94	8474	0	6479	0	0	10	2.50	326	20.86	560	49.23	201	26.84	55	11.00	0	0.00	17.71	64	2000	16680	39360	21456
12	301.19	7958.4	79	42.48	8409	0	6458	0	0	10	2.51	320	20.04	564	49.60	208	27.54	55	11.00	0	0.00	17.40	57	2000	16000	39600	21984
12	300.85	7947.6	79	84.47	8720	0	6607	0	0	6	1.49	328	21.43	558	49.29	195	26.71	58	11.60	0	0.00	17.85	63	1200	17220	39600	21456
12	301.31	7929.2	79	185.08	8559	0	6528	0	0	12	2.99	318	20.31	558	48.74	202	26.89	47	9.40	0	0.00	18.60	63	2400	16280	39060	21552
12	300.89	7951.6	80	247.34	8718	0	6720	0	0	8	2.00	322	20.41	562	49.60	206	27.44	52	10.40	0	0.00	17.37	62	1600	16320	39660	21936
12	300.91	7929.6	78	65.35	8717	0	6659	0	0	12	3.02	318	19.99	562	49.41	205	27.28	50	10.00	0	0.00	19.44	63	2400	15900	39300	21696
36	309.19	7954.0	79	140.29	8965	0	6928	0	0	10	2.49	324	21.40	554	48.58	197	26.60	54	10.80	0	0.00	19.83	63	2000	17180	39000	21360
36	314.14	7922.0	76	75.29	9034	0	6941	0	0	8	1.99	328	20.97	558	49.09	200	26.60	54	10.80	0	0.00	16.83	60	1600	16840	39420	21360
36	324.60	7933.6	79	177.48	9391	0	7093	0	0	10	2.49	326	20.57	560	49.01	198	26.72	56	11.20	0	0.00	16.88	54	2000	16520	39360	21456
36	307.90	7970.4	79	110.98	8973	0	6865	0	0	12	2.98	332	21.82	552	48.03	198	26.09	48	9.60	0	0.00	19.46	58	2400	17580	38700	21024
36	312.08	7944.8	79	233.05	8900	0	6767	0	0	12	3.00	322	20.85	556	48.61	202	26.72	55	11.00	0	0.00	16.35	58	2400	16700	38940	21408
36	315.35	7947.6	79	95.00	9090	0	6922	0	0	6	1.49	328	21.44	558	49.30	195	26.71	58	11.60	0	0.00	17.85	63	1200	17220	39600	21456
36	311.80	7946.0	76	6.97	9095	0	6965	0	0	6	1.49	320	20.91	558	49.24	196	27.16	48	9.60	0	0.00	16.19	54	1200	16820	39600	21840
36	309.05	7944.8	78	126.14	8841	0	6756	0	0	12	3.01	332	21.82	552	48.48	197	26.22	52	10.40	0	0.00	17.38	59	2400	17420	38700	20928
36	311.95	7949.2	80	187.56	9102	0	6917	0	0	4	1.00	312	19.83	570	50.46	202	27.75	57	11.40	0	0.00	17.54	65	800	15920	40500	22272
36	311.78	7926.0	79	258.51	9175	0	6953	0	0	10	2.50	320	20.86	554	48.84	201	27.05	50	10.00	0	0.00	18.87	62	2000	16660	39000	21600
36*	314.92	7952.0	80	129.86	8863	0	6767	0	0	12	3.02	328	21.45	552	48.67	203	26.86	50	10.00	0	0.00	19.04	65	2400	17060	38700	21360
36*	301.98	7970.0	80	82.79	8538	0	6439	0	0	12	3.01	322	20.88	558	49.01	201	27.10	54	10.80	0	0.00	18.54	56	2400	16640	39060	21600
36*	301.50	7933.2	78	295.96	8534	0	6571	0	0	10	2.52	316	21.15	554	49.16	199	27.17	51	10.20	0	0.00	17.06	61	2000	16780	39000	21552
36*	301.91	7954.4	80	143.01	8404	0	6405	0	0	12	3.02	324	21.60	552	48.65	199	26.73	52	10.40	0	0.00	18.79	65	2400	17180	38700	21264
36*	302.11	7951.2	79	161.90	8753	0	6688	0	0	12	3.02	330	21.51	556	48.97	197	26.50	63	12.60	0	0.00	17.15	49	2400	17100	38940	21072
36*	301.77	7929.2	79	182.58	8529	0	6470	0	0	12	3.03	318	20.53	558	49.26	202	27.18	47	9.40	0	0.00	18.60	63	2400	16280	39060	21552
36*	301.72	7944.8	78	99.53	8783	0	6657	0	0	12	3.02	332	21.93	552	48.71	197	26.34	52	10.40	0	0.00	17.38	59	2400	17420	38700	20928
36*	301.98	7964.0	79	8.71	8439	0	6378	0	0	8	2.01	328	21.07	562	49.80	198	27.12	54	10.80	0	0.00	17.15	59	1600	16780	39660	21600
36*	301.56	7920.4	80	268.98	8489	0	6462	0	0	10	2.53	324	20.93	560	49.69	199	26.85	58	11.60	0	0.00	18.52	62	2000	16580	39360	21264
36*	302.37	7926.0	79	259.09	8692	0	6642	0	0	10	2.52	320	21.02	554	49.21	201	27.25	50	10.00	0	0.00	18.87	62	2000	16660	39000	21600

Table D.13: Results of all runs made with GEANT2 network case 2, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	#10G	%10G	#40G	%40G	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	301.11	8820.0	80	249.85	534	0	526	0	0	30	6.80	276	15.65	604	51.70	203	25.85	52	13.00	0	0.00	18.92	70	6000	13800	45600	22800
1	300.47	8874.0	80	173.96	549	0	536	0	0	36	8.11	276	15.55	598	50.37	207	25.96	56	14.00	0	0.00	17.10	64	7200	13800	44700	23040
1	301.45	8840.0	77	202.12	549	0	543	0	0	34	7.69	276	15.61	600	50.91	206	25.79	57	14.25	0	0.00	16.56	65	6800	13800	45000	22800
1	300.93	8850.0	79	246.03	539	0	525	0	0	38	8.59	274	15.48	596	50.17	206	25.76	57	14.25	0	0.00	17.50	63	7600	13700	44400	22800
1	301.11	8859.6	80	210.08	531	0	518	0	0	34	7.68	278	15.69	600	50.79	204	25.84	56	14.00	0	0.00	18.46	67	6800	13900	45000	22896
1	300.81	8792.0	80	145.28	535	0	525	0	0	34	7.73	268	15.42	600	51.18	202	25.66	60	15.00	0	0.00	16.13	62	6800	13560	45000	22560
1	300.58	8859.6	80	216.51	536	0	529	0	0	30	6.77	282	15.91	604	51.47	204	25.84	50	12.50	0	0.00	16.15	64	6000	14100	45600	22896
1	301.19	8868.8	80	188.70	541	0	530	0	0	34	7.67	276	15.56	600	50.74	209	26.03	52	13.00	0	0.00	17.04	68	6800	13800	45000	23088
1	301.24	8860.4	80	158.11	542	0	535	0	0	34	7.67	282	15.91	600	50.79	205	25.62	54	13.50	0	0.00	16.54	66	6800	14100	45000	22704
1	300.50	8850.0	78	21.09	542	0	529	0	0	38	8.59	274	15.48	596	50.17	203	25.76	61	15.25	0	0.00	16.69	69	7600	13700	44400	22800
12	301.44	8805.6	79	256.34	8400	0	8228	0	0	32	7.26	274	15.54	602	51.39	203	25.70	54	13.50	0	0.00	16.60	62	6400	13700	45300	22656
12	300.88	8781.6	79	104.21	8445	0	8291	0	0	36	8.11	270	15.20	598	50.34	202	25.24	57	14.25	0	0.00	17.13	63	7200	13500	44700	22416
12	301.20	8822.4	79	105.57	8378	0	8221	0	0	36	8.13	282	15.91	598	50.45	200	25.08	60	15.00	0	0.00	17.69	66	7200	14100	44700	22224
12	300.94	8815.2	80	116.56	8490	0	8342	0	0	30	6.78	276	15.60	604	51.56	201	25.73	60	15.00	0	0.00	16.87	62	6000	13800	45600	22752
12	301.30	8820.0	80	163.86	8251	0	8123	0	0	32	7.22	274	15.46	602	51.11	203	25.72	51	12.75	0	0.00	18.33	65	6400	13700	45300	22800
12	301.17	8792.0	80	117.55	7834	0	7705	0	0	38	8.59	272	15.38	596	50.20	204	25.24	59	14.75	0	0.00	19.35	67	7600	13600	44400	22320
12	301.19	8811.2	79	139.90	8501	0	8336	0	0	34	7.66	276	15.54	600	50.68	203	25.35	56	14.00	0	0.00	17.27	74	6800	13800	45000	22512
12	301.42	8829.6	79	133.77	8500	0	8342	0	0	34	7.70	272	15.39	600	50.93	207	25.92	49	12.25	0	0.00	19.15	64	6800	13600	45000	22896
12	305.12	8820.0	79	83.06	8246	0	8094	0	0	34	7.66	272	15.33	600	50.71	206	25.70	49	12.25	0	0.00	17.50	63	6800	13600	45000	22800
12	300.78	8795.6	79	141.65	8404	0	8271	0	0	34	7.72	270	15.33	600	51.10	203	25.73	55	13.75	0	0.00	17.71	67	6800	13500	45000	22656
36	307.43	8781.6	79	230.72	8433	0	8272	0	0	36	8.11	270	15.20	598	50.32	202	25.23	57	14.25	0	0.00	17.13	63	7200	13500	44700	22416
36	312.94	8785.6	80	81.45	8807	0	8656	0	0	36	8.12	266	14.99	598	50.39	203	25.54	56	14.00	0	0.00	17.12	63	7200	13300	44700	22656
36	311.05	8792.0	80	80.64	8671	0	8503	0	0	38	8.53	272	15.27	596	49.84	204	25.06	59	14.75	0	0.00	19.35	67	7600	13600	44400	22320
36	315.28	8791.6	79	133.04	8987	0	8812	0	0	36	8.11	272	15.32	598	50.36	202	25.26	51	12.75	0	0.00	16.54	62	7200	13600	44700	22416
36	318.68	8819.6	79	195.45	8904	0	8754	0	0	30	6.77	274	15.46	604	51.44	204	25.83	56	14.00	0	0.00	15.63	63	6000	13700	45600	22896
36	306.85	8821.6	80	67.80	8754	0	8598	0	0	42	9.45	272	15.30	592	49.27	202	25.22	54	13.50	0	0.00	18.37	71	8400	13600	43800	22416
36	307.80	8808.0	78	87.38	8692	0	8519	0	0	32	7.18	278	15.76	602	50.79	198	25.03	60	15.00	0	0.00	18.54	67	6400	14060	45300	22320
36	313.37	8769.2	80	289.30	8837	0	8664	0	0	36	8.09	272	15.45	598	50.20	201	24.75	53	13.25	0	0.00	17.38	62	7200	13760	44700	22032
36	312.14	8801.2	79	32.21	8890	0	8724	0	0	36	8.12	272	15.34	598	50.43	203	25.40	59	14.75	0	0.00	19.69	64	7200	13600	44700	22512
36	307.48	8810.4	79	237.11	8501	0	8328	0	0	34	7.66	272	15.31	600	50.67	205	25.57	57	14.25	0	0.00	17.29	62	6800	13600	45000	22704
36*	302.13	8810.8	80	258.16	8021	0	7882	0	0	34	7.72	274	15.55	600	51.07	204	25.66	56	14.00	0	0.00	16.81	64	6800	13700	45000	22608
36*	302.03	8820.0	80	167.29	8033	0	7893	0	0	34	7.71	272	15.42	600	51.02	203	25.85	56	14.00	0	0.00	17.58	66	6800	13600	45000	22800
36*	301.89	8791.2	78	127.36	8340	0	8197	0	0	34	7.74	272	15.47	600	51.19	203	25.61	57	14.25	0	0.00	16.06	63	6800	13600	45000	22512
36*	302.13	8809.6	80	164.16	8267	0	8107	0	0	30	6.81	272	15.44	604	51.76	201	25.99	58	14.50	0	0.00	17.46	71	6000	13600	45600	22896
36*	302.11	8830.0	79	78.70	8380	0	8231	0	0	38	8.61	270	15.29	596	50.28	206	25.82	53	13.25	0	0.00	17.40	63	7600	13500	44400	22800
36*	301.83	8810.8	78	69.87	8572	0	8393	0	0	30	6.81	278	15.78	604	51.75	201	25.66	64	16.00	0	0.00	15.88	62	6000	13900	45600	22608
36*	302.02	8811.2	79	236.06	8600	0	8439	0	0	36	8.17	274	15.55	598	50.73	206	25.55	54	13.50	0	0.00	17.75	63	7200	13700	44700	22512
36*	301.45	8805.6	79	20.44	8568	0	8398	0	0	28	6.36	278	15.79	606	52.13	200	25.73	58	14.50	0	0.00	16.65	66	5600	13900	45900	22656
36*	302.09	8829.6	79	175.83	7962	0	7815	0	0	36	8.15	270	15.29	598	50.63	207	25.93	53	13.25	0	0.00	18.10	68	7200	13500	44700	22896
36*	301.94	8801.2	79	32.42	8385	0	8216	0	0	36	8.18	272	15.45	598	50.79	203	25.58	59	14.75	0	0.00	19.69	64	7200	13600	44700	22512

Table D.14: Results of all runs made with GEANT2 network case 3, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	301.14	9548.0	80	69.03	214	0	214	0	0	20	4.19	662	36.68	342	27.71	272	31.42	99	8.61	0	0.00	16.96	55	4000	35020	26460	30000
1	301.42	9668.4	80	291.10	215	0	215	0	0	20	4.14	672	36.57	342	27.37	278	31.92	98	8.52	0	0.00	16.96	56	4000	35360	26460	30864
1	301.31	9616.4	80	98.03	219	0	219	0	0	20	4.16	676	36.48	342	27.52	274	31.85	91	7.91	0	0.00	17.33	57	4000	35080	26460	30624
1	301.67	9602.8	80	209.09	216	0	216	0	0	18	3.75	658	36.59	344	27.87	273	31.79	105	9.13	0	0.00	18.06	55	3600	35140	26760	30528
1	300.85	9677.2	80	230.02	220	0	220	0	0	22	4.55	660	35.98	336	26.78	289	32.69	92	8.00	0	0.00	17.79	57	4400	34820	25920	31632
1	301.31	9628.0	80	76.41	216	0	216	0	0	18	3.74	672	37.06	344	27.79	273	31.41	100	8.70	0	0.00	17.73	54	3600	35680	26760	30240
1	300.58	9636.0	80	70.68	219	0	219	0	0	24	4.98	676	36.80	334	26.59	277	31.63	100	8.70	0	0.00	16.81	58	4800	35460	25620	30480
1	301.78	9621.2	80	1.83	220	0	220	0	0	18	3.74	656	36.81	340	27.56	267	31.88	103	8.96	0	0.00	16.46	56	3600	35420	26520	30672
1	302.09	9668.0	80	239.60	216	0	216	0	0	20	4.14	670	36.97	342	27.37	271	31.53	95	8.26	0	0.00	17.12	55	4000	35740	26460	30480
1	301.00	9616.4	80	62.62	215	0	215	0	0	24	4.99	674	36.77	334	26.64	279	31.60	89	7.74	0	0.00	17.75	59	4800	35360	25620	30384
12	302.22	9546.8	80	219.51	2303	0	2303	0	0	22	4.54	662	35.97	340	26.99	271	31.01	95	8.26	0	0.00	18.83	56	4400	34860	26160	30048
12	302.33	9558.0	80	208.68	2330	0	2330	0	0	16	3.31	668	36.51	346	27.97	272	31.01	106	9.22	0	0.00	17.77	56	3200	35320	27060	30000
12	302.09	9555.6	80	223.03	2290	0	2289	0	0	18	3.72	662	36.01	344	27.64	277	31.34	101	8.78	0	0.00	17.23	58	3600	34860	26760	30336
12	302.95	9597.6	80	276.21	2302	0	2302	0	0	16	3.32	666	36.16	346	28.04	276	31.93	106	9.22	0	0.00	17.27	55	3200	34900	27060	30816
12	302.33	9530.8	80	176.45	2323	0	2323	0	0	20	4.17	664	36.78	342	27.59	263	30.83	110	9.57	0	0.00	17.27	59	4000	35280	26460	29568
12	301.83	9592.4	80	209.23	2349	0	2349	0	0	16	3.30	664	36.35	346	27.88	273	31.31	101	8.78	0	0.00	17.73	54	3200	35280	27060	30384
12	302.73	9509.6	80	280.32	2334	0	2334	0	0	18	3.72	672	36.00	344	27.62	272	30.82	100	8.70	0	0.00	17.98	57	3600	34880	26760	29856
12	302.22	9618.0	80	89.48	2349	0	2346	0	0	22	4.55	674	36.34	340	27.05	280	31.52	92	8.00	0	0.00	17.38	58	4400	35140	26160	30480
12	303.56	9518.8	80	21.54	2300	0	2300	0	0	20	4.16	668	36.10	342	27.54	274	31.28	107	9.30	0	0.00	18.62	57	4000	34680	26460	30048
12	302.22	9586.4	80	235.36	2331	0	2331	0	0	20	4.13	654	35.93	342	27.34	277	31.64	98	8.52	0	0.00	17.75	56	4000	34780	26460	30624
36	314.71	9580.4	80	230.55	2447	0	2447	0	0	18	3.69	674	36.17	344	27.42	269	30.88	102	8.87	0	0.00	17.35	58	3600	35300	26760	30144
36	309.27	9587.6	80	129.57	2430	0	2430	0	0	18	3.69	670	36.29	344	27.42	270	30.83	99	8.61	0	0.00	17.12	57	3600	35420	26760	30096
36	319.02	9571.6	80	81.42	2412	0	2412	0	0	16	3.28	680	36.47	346	27.72	266	30.59	91	7.91	0	0.00	17.42	59	3200	35600	27060	29856
36	313.54	9615.6	80	64.91	2438	0	2438	0	0	20	4.07	664	35.27	342	26.95	280	31.63	88	7.65	0	0.00	18.48	58	4000	34640	26460	31056
36	313.86	9595.2	80	57.89	2457	0	2457	0	0	24	4.92	670	36.47	338	26.51	272	30.46	91	7.91	0	0.00	17.92	57	4800	35580	25860	29712
36	313.12	9494.0	80	109.84	2449	0	2449	0	0	20	4.12	672	36.24	342	27.24	266	30.15	115	10.00	0	0.00	17.33	57	4000	35200	26460	29280
36	319.21	9602.0	80	231.21	2510	0	2509	0	0	18	3.70	662	35.70	344	27.53	279	31.85	92	8.00	0	0.00	17.46	59	3600	34700	26760	30960
36	321.34	9615.2	80	160.20	2486	0	2486	0	0	22	4.54	660	36.52	340	26.99	274	31.15	101	8.78	0	0.00	16.85	54	4400	35400	26160	30192
36	308.65	9594.8	80	61.28	2407	0	2407	0	0	18	3.72	674	36.47	344	27.64	269	31.29	110	9.57	0	0.00	18.15	58	3600	35300	26760	30288
36	315.35	9586.8	80	4.99	2403	0	2403	0	0	20	4.12	688	36.40	342	27.24	274	30.93	104	9.04	0	0.00	17.83	60	4000	35360	26460	30048
36*	305.01	9558.0	80	122.07	2360	0	2359	0	0	20	4.19	672	36.49	342	27.68	276	31.64	96	8.35	0	0.00	18.50	56	4000	34880	26460	30240
36*	303.75	9557.6	80	213.24	2355	0	2355	0	0	22	4.60	660	36.54	340	27.37	276	31.49	101	8.78	0	0.00	17.62	61	4400	34920	26160	30096
36*	303.69	9494.0	80	189.82	2369	0	2369	0	0	20	4.21	672	37.08	342	27.87	266	30.84	115	10.00	0	0.00	17.33	57	4000	35200	26460	29280
36*	304.61	9570.8	80	155.45	2370	0	2370	0	0	30	6.27	662	36.76	332	26.08	272	30.89	104	9.04	0	0.00	19.15	60	6000	35180	24960	29568
36*	303.73	9584.4	80	142.87	2356	0	2355	0	0	20	4.17	668	36.52	342	27.61	276	31.70	98	8.52	0	0.00	18.10	58	4000	35000	26460	30384
36*	303.64	9588.0	80	25.02	2345	0	2345	0	0	20	4.17	672	36.94	338	27.35	273	31.54	99	8.61	0	0.00	16.38	56	4000	35420	26220	30240
36*	303.30	9556.4	80	18.97	2354	0	2354	0	0	20	4.19	672	36.83	342	27.69	268	31.29	106	9.22	0	0.00	17.10	53	4000	35200	26460	29904
36*	303.90	9573.2	80	290.74	2319	0	2319	0	0	20	4.18	660	36.14	342	27.64	276	32.04	93	8.09	0	0.00	18.92	57	4000	34600	26460	30672
36*	303.54	9595.2	80	67.13	2358	0	2358	0	0	24	5.00	670	37.08	338	26.95	272	30.97	91	7.91	0	0.00	17.92	57	4800	35580	25860	29712
36*	304.01	9523.2	80	26.91	2371	0	2371	0	0	20	4.20	658	36.56	342	27.78	276	31.45	97	8.43	0	0.00	17.92	55	4000	34820	26460	29952

Table D.15: Results of all runs made with GEANT2 network case 4, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
#T	t_E	C	CA	t_{sol}	#i	#IS	#G_U	#LS_U	UD	#IM	C_{IM}	#MX	C_{MX}	#TX	C_{TX}	#3R	C_{3R}	#10G	%10G	#40G	%40G	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	301.55	9296.4	78	36.66	334	0	333	0	0	28	6.02	396	21.47	634	46.53	226	25.97	89	15.48	0	0.00	15.63	61	5600	19960	43260	24144
1	301.14	9280.8	79	53.65	338	0	337	0	0	22	4.74	404	21.77	640	47.58	219	25.91	91	15.83	0	0.00	14.00	56	4400	20200	44160	24048
1	300.74	9272.0	79	184.88	341	0	338	0	0	30	6.47	392	21.31	632	46.33	229	25.88	90	15.65	0	0.00	16.88	55	6000	19760	42960	24000
1	301.49	9271.2	79	88.89	335	0	334	0	0	28	6.04	398	21.46	634	46.66	227	25.83	96	16.70	0	0.00	16.98	62	5600	19900	43260	23952
1	300.75	9344.8	79	227.67	335	0	335	0	0	30	6.42	396	21.36	632	45.97	233	26.25	93	16.17	0	0.00	16.29	58	6000	19960	42960	24528
1	300.78	9310.4	80	79.17	341	0	341	0	0	28	6.01	394	21.33	634	46.46	230	26.19	88	15.30	0	0.00	14.04	58	5600	19860	43260	24384
1	301.11	9324.8	78	278.01	333	0	331	0	0	30	6.43	400	21.45	632	46.07	232	26.05	94	16.35	0	0.00	15.27	56	6000	20000	42960	24288
1	301.14	9316.0	80	76.89	334	0	333	0	0	30	6.44	404	21.68	632	46.11	229	25.76	94	16.35	0	0.00	16.23	55	6000	20200	42960	24000
1	301.08	9282.8	79	274.90	335	0	335	0	0	24	5.17	404	21.93	638	47.25	218	25.65	102	17.74	0	0.00	14.60	49	4800	20360	43860	23808
1	300.53	9256.8	79	184.38	335	0	333	0	0	30	6.48	396	21.39	632	46.41	227	25.72	101	17.57	0	0.00	16.29	55	6000	19800	42960	23808
12	301.38	9261.6	77	250.99	3537	0	3524	0	0	28	6.02	390	21.13	634	46.49	227	25.89	87	15.13	0	0.00	15.92	60	5600	19660	43260	24096
12	301.91	9289.2	80	252.39	3563	0	3544	0	0	30	6.43	400	21.66	628	45.77	224	25.66	81	14.09	0	0.00	14.42	49	6000	20220	42720	23952
12	301.94	9237.2	80	95.66	3562	0	3545	0	0	30	6.45	394	21.16	632	46.15	226	25.47	94	16.35	0	0.00	15.00	57	6000	19700	42960	23712
12	301.67	9228.8	80	12.79	3558	0	3540	0	0	28	5.99	402	21.51	634	46.29	219	24.96	93	16.17	0	0.00	15.58	60	5600	20100	43260	23328
12	301.27	9251.6	79	209.18	3647	0	3628	0	0	30	6.44	394	21.14	632	46.09	226	25.60	91	15.83	0	0.00	14.98	55	6000	19700	42960	23856
12	301.66	9294.4	78	107.27	3610	0	3594	0	0	30	6.44	402	21.82	628	45.88	225	25.67	85	14.78	0	0.00	16.08	46	6000	20320	42720	23904
12	301.81	9264.8	79	149.74	3603	0	3582	0	0	30	6.43	388	20.78	632	46.02	229	26.02	88	15.30	0	0.00	18.25	52	6000	19400	42960	24288
12	301.45	9237.6	79	98.95	3606	0	3592	0	0	28	6.06	398	21.52	634	46.79	219	25.54	93	16.17	0	0.00	17.31	62	5600	19900	43260	23616
12	301.91	9252.4	79	159.10	3624	0	3610	0	0	28	6.02	400	21.51	634	46.53	224	25.45	89	15.48	0	0.00	15.63	54	5600	20000	43260	23664
12	302.14	9267.2	80	83.24	3565	0	3553	0	0	30	6.44	400	21.47	632	46.12	226	25.46	88	15.30	0	0.00	15.71	53	6000	20000	42960	23712
36	311.44	9266.8	79	149.07	3702	0	3691	0	0	28	5.98	410	22.14	630	45.97	219	24.93	94	16.35	0	0.00	15.77	53	5600	20720	43020	23328
36	312.78	9245.6	76	93.65	3690	0	3675	0	0	32	6.90	402	21.84	630	45.99	220	24.94	99	17.22	0	0.00	15.83	50	6400	20260	42660	23136
36	308.38	9241.6	79	258.23	3651	0	3631	0	0	26	5.55	396	21.13	636	46.47	223	25.45	86	14.96	0	0.00	16.58	59	5200	19800	43560	23856
36	312.87	9279.2	78	236.45	3700	0	3687	0	0	32	6.84	402	21.65	630	45.59	222	25.08	95	16.52	0	0.00	16.21	61	6400	20260	42660	23472
36	310.21	9220.8	79	23.59	3713	0	3700	0	0	22	4.69	392	20.91	640	47.12	219	25.66	88	15.30	0	0.00	16.52	58	4400	19600	44160	24048
36	313.11	9256.8	78	3.34	3664	0	3651	0	0	30	6.44	396	21.25	632	46.10	227	25.55	100	17.39	0	0.00	15.37	59	6000	19800	42960	23808
36	310.35	9270.8	78	151.35	3706	0	3689	0	0	28	6.01	396	21.26	634	46.45	228	25.82	101	17.57	0	0.00	15.94	54	5600	19800	43260	24048
36	314.96	9228.0	80	174.19	3780	0	3766	0	0	30	6.39	396	21.09	632	45.76	221	25.05	94	16.35	0	0.00	15.38	54	6000	19800	42960	23520
36	313.37	9262.4	79	70.22	3760	0	3743	0	0	28	5.99	402	21.49	634	46.25	221	25.30	102	17.74	0	0.00	16.23	51	5600	20100	43260	23664
36	307.87	9233.6	75	193.71	3609	0	3591	0	0	28	5.98	394	21.19	634	46.16	222	25.20	95	16.52	0	0.00	16.27	57	5600	19860	43260	23616
36*	302.84	9241.6	79	60.75	3498	0	3478	0	0	26	5.63	396	21.42	636	47.13	223	25.81	86	14.96	0	0.00	16.58	59	5200	19800	43560	23856
36*	302.62	9266.0	80	131.98	3560	0	3541	0	0	28	6.04	396	21.37	634	46.69	223	25.90	93	16.17	0	0.00	17.12	57	5600	19800	43260	24000
36*	306.40	9243.6	80	219.95	3655	0	3639	0	0	32	6.92	392	21.38	630	46.15	225	25.55	97	16.87	0	0.00	16.96	66	6400	19760	42660	23616
36*	303.14	9256.0	80	284.75	3555	0	3541	0	0	30	6.48	392	21.18	632	46.41	229	25.93	91	15.83	0	0.00	15.35	49	6000	19600	42960	24000
36*	302.61	9261.6	77	133.52	3597	0	3588	0	0	28	6.05	390	21.23	634	46.71	224	26.02	90	15.65	0	0.00	14.85	55	5600	19660	43260	24096
36*	318.30	9286.8	79	215.72	3572	0	3558	0	0	30	6.46	402	21.64	632	46.26	227	25.64	87	15.13	0	0.00	15.85	51	6000	20100	42960	23808
36*	302.91	9297.2	79	51.23	3614	0	3600	0	0	30	6.45	406	21.83	632	46.21	226	25.50	88	15.30	0	0.00	17.27	56	6000	20300	42960	23712
36*	303.26	9240.8	78	299.72	3425	0	3410	0	0	30	6.49	388	20.99	632	46.49	225	26.02	90	15.65	0	0.00	15.19	57	6000	19400	42960	24048
36*	305.90	9281.2	79	219.45	3532	0	3515	0	0	28	6.03	400	21.55	634	46.61	227	25.81	100	17.39	0	0.00	15.35	57	5600	20000	43260	23952
36*	303.26	9253.2	80	231.11	3502	0	3486	0	0	30	6.48	394	21.46	632	46.43	226	25.63	89	15.48	0	0.00	16.12	58	6000	19860	42960	23712

Table D.16: Results of all runs made with GEANT2 network case 5, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	301.18	10247.2	80	195.83	322	0	322	0	0	40	7.81	338	16.71	688	50.47	234	25.01	90	19.57	0	0.00	17.71	66	8000	17120	51720	25632
1	300.61	10258.0	80	33.48	323	0	322	0	0	36	7.02	334	16.71	688	50.77	229	25.50	84	18.26	0	0.00	19.15	65	7200	17140	52080	26160
1	302.17	10244.8	80	184.00	318	0	317	0	0	34	6.64	342	17.12	690	51.13	226	25.11	87	18.91	0	0.00	19.81	63	6800	17540	52380	25728
1	300.78	10222.0	80	13.96	322	0	322	0	0	36	7.04	336	16.65	692	51.18	227	25.12	84	18.26	0	0.00	18.00	66	7200	17020	52320	25680
1	301.03	10249.2	80	71.37	318	0	317	0	0	36	7.02	338	16.92	688	50.81	229	25.24	93	20.22	0	0.00	17.38	66	7200	17340	52080	25872
1	301.80	10236.8	79	144.30	320	0	319	0	0	38	7.42	336	16.63	690	50.82	229	25.13	90	19.57	0	0.00	19.15	66	7600	17020	52020	25728
1	300.83	10263.6	80	110.32	323	0	323	0	0	36	7.02	344	17.13	692	50.98	224	24.88	97	21.09	0	0.00	17.79	63	7200	17580	52320	25536
1	301.31	10257.2	80	11.78	317	0	317	0	0	36	7.02	336	16.75	692	51.01	229	25.22	88	19.13	0	0.00	18.96	65	7200	17180	52320	25872
1	300.71	10189.6	80	4.59	323	0	323	0	0	30	5.89	340	17.06	698	52.23	217	24.83	95	20.65	0	0.00	17.75	55	6000	17380	53220	25296
1	301.49	10239.2	80	201.16	324	0	324	0	0	38	7.42	338	16.51	694	51.04	228	25.03	91	19.78	0	0.00	18.87	66	7600	16900	52260	25632
12	301.89	10156.8	80	36.99	3355	0	3353	0	0	38	7.43	326	16.09	694	51.08	227	24.68	88	19.13	0	0.00	18.44	64	7600	16460	52260	25248
12	302.00	10209.6	79	185.33	3145	0	3140	0	0	32	6.25	328	16.60	692	51.44	223	25.40	89	19.35	0	0.00	18.96	61	6400	17000	52680	26016
12	301.66	10146.8	77	87.20	3397	0	3392	0	0	36	7.06	334	16.37	696	51.53	223	24.52	84	18.26	0	0.00	17.83	58	7200	16700	52560	25008
12	301.63	10167.6	80	169.07	3359	0	3356	0	0	38	7.40	336	16.79	686	50.44	222	24.41	90	19.57	0	0.00	19.67	59	7600	17240	51780	25056
12	301.98	10200.8	80	192.65	3331	0	3323	0	0	30	5.84	342	17.08	694	51.59	219	24.82	89	19.35	0	0.00	18.88	61	6000	17540	52980	25488
12	301.70	10173.6	80	111.06	3343	0	3340	0	0	38	7.43	332	16.45	690	50.88	226	24.74	92	20.00	0	0.00	19.37	60	7600	16820	52020	25296
12	301.64	10207.6	79	261.89	3370	0	3366	0	0	40	7.78	332	16.35	688	50.29	227	24.83	87	18.91	0	0.00	18.27	64	8000	16820	51720	25536
12	301.78	10189.6	80	4.07	3394	0	3385	0	0	38	7.39	340	16.75	690	50.61	222	24.37	89	19.35	0	0.00	17.40	60	7600	17220	52020	25056
12	301.30	10209.2	80	12.50	3385	0	3379	0	0	40	7.84	340	16.87	688	50.66	223	24.64	90	19.57	0	0.00	18.02	60	8000	17220	51720	25152
12	301.94	10142.4	78	262.30	3365	0	3359	0	0	36	7.10	336	16.56	696	51.82	220	24.51	89	19.35	0	0.00	19.71	65	7200	16800	52560	24864
36	314.37	10202.4	79	11.43	3520	0	3511	0	0	36	6.99	336	16.89	688	50.56	225	24.60	94	20.43	0	0.00	18.44	65	7200	17400	52080	25344
36	316.31	10185.6	79	7.02	3575	0	3569	0	0	34	6.64	338	16.49	698	51.58	223	24.68	88	19.13	0	0.00	19.19	58	6800	16900	52860	25296
36	314.01	10183.6	80	162.46	3512	0	3509	0	0	34	6.60	338	16.60	694	51.04	223	24.53	87	18.91	0	0.00	20.54	67	6800	17120	52620	25296
36	313.89	10206.8	80	293.50	3528	0	3517	0	0	40	7.75	338	16.79	684	49.85	224	24.45	90	19.57	0	0.00	18.71	65	8000	17340	51480	25248
36	307.91	10185.6	79	72.82	3484	0	3475	0	0	38	7.41	344	16.98	690	50.71	218	24.19	95	20.65	0	0.00	17.90	58	7600	17420	52020	24816
36	313.20	10178.4	80	265.64	3518	0	3513	0	0	36	6.98	334	16.40	692	50.73	225	24.57	83	18.04	0	0.00	19.92	63	7200	16920	52320	25344
36	313.64	10154.8	79	154.44	3520	0	3513	0	0	28	5.44	326	15.98	704	52.18	223	24.97	91	19.78	0	0.00	19.85	62	5600	16460	53760	25728
36	307.20	10190.8	80	25.08	3484	0	3476	0	0	38	7.35	336	16.26	694	50.57	224	24.43	105	22.83	0	0.00	17.73	60	7600	16800	52260	25248
36	313.79	10156.8	80	220.71	3458	0	3452	0	0	38	7.37	326	15.95	694	50.66	227	24.47	88	19.13	0	0.00	18.44	64	7600	16460	52260	25248
36	315.88	10171.2	80	8.42	3559	0	3556	0	0	34	6.59	334	16.62	690	50.79	221	24.62	104	22.61	0	0.00	19.27	60	6800	17140	52380	25392
36*	303.48	10202.4	79	16.05	3440	0	3435	0	0	36	7.06	336	17.05	688	51.05	225	24.84	94	20.43	0	0.00	18.44	65	7200	17400	52080	25344
36*	302.92	10185.6	79	11.30	3406	0	3402	0	0	34	6.68	338	16.59	698	51.90	223	24.84	88	19.13	0	0.00	19.19	58	6800	16900	52860	25296
36*	303.17	10184.8	80	117.13	3408	0	3401	0	0	38	7.46	330	16.20	694	51.31	228	25.03	87	18.91	0	0.00	17.33	59	7600	16500	52260	25488
36*	302.47	10187.6	80	264.08	3421	0	3413	0	0	32	6.28	336	16.71	696	51.95	227	25.07	78	16.96	0	0.00	17.92	66	6400	17020	52920	25536
36*	303.50	10174.0	80	282.47	3429	0	3427	0	0	32	6.29	340	16.93	696	52.01	219	24.77	83	18.04	0	0.00	19.42	59	6400	17220	52920	25200
36*	302.78	10204.8	80	93.66	3385	0	3380	0	0	36	7.06	336	16.46	696	51.51	225	24.98	98	21.30	0	0.00	17.73	67	7200	16800	52560	25488
36*	302.84	10230.8	80	218.56	3350	0	3344	0	0	36	7.04	338	16.68	696	51.37	225	24.91	89	19.35	0	0.00	20.06	67	7200	17060	52560	25488
36*	303.36	10172.0	80	216.58	3431	0	3426	0	0	42	8.26	334	16.42	690	50.79	227	24.54	85	18.48	0	0.00	17.44	62	8400	16700	51660	24960
36*	302.72	10189.6	80	16.47	3419	0	3412	0	0	38	7.46	340	16.90	690	51.05	222	24.59	89	19.35	0	0.00	17.40	60	7600	17220	52020	25056
36*	303.40	10156.8	80	187.29	3395	0	3391	0	0	38	7.48	326	16.21	694	51.45	227	24.86	88	19.13	0	0.00	18.44	64	7600	16460	52260	25248

Table D.17: Results of all runs made with GEANT2 network case 6, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	301.71	10515.6	80	27.08	150	0	149	0	0	20	3.80	784	38.25	390	29.10	286	28.85	119	8.99	0	0.00	14.40	59	4000	40220	30600	30336
1	301.84	10621.6	80	93.01	152	0	151	0	0	12	2.26	792	38.34	402	30.16	286	29.24	124	9.37	0	0.00	16.02	56	2400	40720	32040	31056
1	302.02	10474.4	80	224.39	152	0	152	0	0	16	3.06	792	38.84	390	29.56	277	28.55	104	7.86	0	0.00	16.13	56	3200	40680	30960	29904
1	302.67	10577.2	79	16.37	152	0	152	0	0	10	1.89	778	38.31	392	29.89	289	29.91	120	9.07	0	0.00	14.94	55	2000	40520	31620	31632
1	301.11	10592.8	80	246.90	152	0	152	0	0	20	3.78	778	38.74	390	28.89	281	28.59	133	10.05	0	0.00	14.85	54	4000	41040	30600	30288
1	300.99	10661.2	80	184.72	151	0	151	0	0	16	3.00	794	37.84	398	29.49	301	29.67	117	8.84	0	0.00	14.04	54	3200	40340	31440	31632
1	302.76	10630.8	80	176.19	155	0	155	0	0	16	3.01	782	38.25	390	29.12	289	29.62	117	8.84	0	0.00	14.94	55	3200	40660	30960	31488
1	301.30	10538.4	80	173.16	152	0	152	0	0	16	3.04	790	38.75	394	29.61	278	28.60	128	9.67	0	0.00	15.10	54	3200	40840	31200	30144
1	301.97	10592.0	80	287.10	152	0	152	0	0	10	1.89	794	38.80	396	30.08	279	29.23	120	9.07	0	0.00	14.08	56	2000	41100	31860	30960
1	301.36	10582.8	80	260.40	155	0	155	0	0	16	3.02	778	37.97	398	29.71	287	29.30	121	9.15	0	0.00	15.87	53	3200	40180	31440	31008
12	303.83	10513.6	80	81.81	1547	0	1544	0	0	14	2.64	778	37.71	400	29.91	284	28.81	124	9.37	0	0.00	16.48	57	2800	40020	31740	30576
12	302.97	10495.2	80	97.69	1602	0	1597	0	0	16	3.03	782	38.49	394	29.58	276	28.40	118	8.92	0	0.00	16.19	54	3200	40600	31200	29952
12	303.54	10493.6	80	66.83	1586	0	1585	0	0	14	2.65	778	38.15	392	29.59	284	28.94	123	9.30	0	0.00	14.02	56	2800	40300	31260	30576
12	303.00	10537.2	80	103.68	1589	0	1587	0	0	18	3.39	784	38.54	388	28.87	283	28.43	117	8.84	0	0.00	15.27	54	3600	40920	30660	30192
12	303.25	10519.2	80	152.33	1561	0	1561	0	0	16	3.01	784	38.21	390	29.14	284	28.64	116	8.77	0	0.00	15.21	55	3200	40600	30960	30432
12	303.11	10514.8	80	35.10	1582	0	1580	0	0	14	2.64	786	38.52	396	29.74	280	28.37	128	9.67	0	0.00	15.04	57	2800	40800	31500	30048
12	303.11	10558.0	80	2.98	1576	0	1575	0	0	16	3.02	778	38.59	390	29.18	280	28.73	136	10.28	0	0.00	16.19	57	3200	40940	30960	30480
12	303.64	10447.6	79	211.41	1580	0	1578	0	0	18	3.40	776	38.57	388	28.96	273	27.74	107	8.09	0	0.00	15.79	56	3600	40840	30660	29376
12	303.11	10557.2	79	136.33	1568	0	1564	0	0	16	3.00	778	37.97	398	29.47	281	28.53	124	9.37	0	0.00	14.58	51	3200	40500	31440	30432
12	303.47	10490.8	80	151.84	1569	0	1566	0	0	16	3.02	784	38.01	394	29.48	281	28.62	117	8.84	0	0.00	15.08	55	3200	40220	31200	30288
36	320.19	10504.8	80	120.43	1661	0	1659	0	0	18	3.35	790	37.95	388	28.56	283	27.99	119	8.99	0	0.00	16.67	56	3600	40740	30660	30048
36	317.96	10551.6	80	227.40	1650	0	1647	0	0	18	3.38	780	38.00	396	29.26	286	28.51	121	9.15	0	0.00	14.38	53	3600	40440	31140	30336
36	317.10	10505.2	80	256.96	1649	0	1649	0	0	16	2.99	784	38.06	394	29.18	279	28.01	121	9.15	0	0.00	16.90	55	3200	40700	31200	29952
36	313.08	10522.4	80	60.50	1597	0	1593	0	0	18	3.36	782	38.13	388	28.64	281	28.16	134	10.13	0	0.00	14.19	59	3600	40820	30660	30144
36	317.51	10529.2	80	289.68	1632	0	1631	0	0	18	3.36	784	37.89	388	28.62	287	28.40	112	8.47	0	0.00	14.77	50	3600	40600	30660	30432
36	315.31	10552.8	80	45.33	1621	0	1620	0	0	16	3.03	780	37.96	398	29.75	286	29.11	109	8.24	0	0.00	16.38	55	3200	40120	31440	30768
36	309.99	10496.0	80	80.04	1616	0	1616	0	0	16	3.02	780	38.26	390	29.21	279	28.53	105	7.94	0	0.00	16.15	56	3200	40560	30960	30240
36	313.62	10506.4	80	276.48	1627	0	1623	0	0	20	3.76	786	38.32	390	28.74	279	27.86	119	8.99	0	0.00	15.73	53	4000	40800	30600	29664
36	310.33	10508.8	80	293.19	1624	0	1622	0	0	20	3.74	782	37.79	390	28.59	283	28.08	115	8.69	0	0.00	15.62	58	4000	40440	30600	30048
36	310.36	10501.6	80	69.75	1622	0	1621	0	0	14	2.64	774	37.82	400	29.91	280	28.58	121	9.15	0	0.00	15.65	52	2800	40140	31740	30336
36*	304.89	10544.4	78	301.99	1554	0	1553	0	0	14	2.66	792	38.88	392	29.65	279	28.82	132	9.98	0	0.00	14.69	49	2800	41000	31260	30384
36*	306.91	10466.8	80	53.59	1580	0	1580	0	0	20	3.82	774	38.46	386	29.01	286	28.71	118	8.92	0	0.00	13.87	61	4000	40260	30360	30048
36*	304.50	10535.6	80	72.90	1527	0	1525	0	0	14	2.66	796	39.11	392	29.67	279	28.57	125	9.45	0	0.00	17.12	56	2800	41200	31260	30096
36*	306.29	10541.6	80	175.52	1581	0	1575	0	0	16	3.04	782	38.36	394	29.60	284	29.01	115	8.69	0	0.00	15.67	57	3200	40440	31200	30576
36*	306.37	10503.6	80	145.22	1586	0	1584	0	0	18	3.43	784	38.96	388	29.19	278	28.42	119	8.99	0	0.00	14.81	56	3600	40920	30660	29856
36*	304.84	10516.8	80	237.00	1587	0	1585	0	0	18	3.42	784	38.40	392	29.38	287	28.80	125	9.45	0	0.00	15.29	53	3600	40380	30900	30288
36*	305.76	10531.2	80	240.82	1557	0	1557	0	0	14	2.66	788	38.53	396	29.91	284	28.90	113	8.54	0	0.00	14.65	51	2800	40580	31500	30432
36*	305.31	10496.0	80	77.69	1577	0	1575	0	0	16	3.05	780	38.64	390	29.50	279	28.81	105	7.94	0	0.00	16.15	56	3200	40560	30960	30240
36*	305.99	10513.2	80	161.77	1581	0	1579	0	0	18	3.42	782	38.47	392	29.39	280	28.72	119	8.99	0	0.00	15.35	60	3600	40440	30900	30192
36*	306.41	10447.6	79	216.56	1572	0	1571	0	0	18	3.45	776	39.09	388	29.35	273	28.12	107	8.09	0	0.00	15.79	56	3600	40840	30660	29376

Table D.18: Results of all runs made with GEANT2 network case 7, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
#T	t_E	C	CA	t_{sol}	#i	#IS	$\#G_U$	$\#LS_U$	UD	#IM	C_{IM}	#MX	C_{MX}	#TX	C_{TX}	#3R	C_{3R}	#10G	%10G	#40G	%40G	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.69	11018.4	80	266.28	137	0	137	0	0	36	6.53	470	21.67	724	44.65	286	27.14	132	19.94	0	0.00	17.27	53	7200	23880	49200	29904
1	301.67	11002.8	80	143.30	135	0	135	0	0	36	6.54	482	22.30	720	44.50	283	26.66	136	20.54	0	0.00	17.60	64	7200	24540	48960	29328
1	302.69	11040.4	80	108.34	139	0	139	0	0	32	5.80	472	21.58	728	45.11	291	27.52	123	18.58	0	0.00	16.85	52	6400	23820	49800	30384
1	302.48	11026.8	80	121.20	136	0	136	0	0	34	6.17	464	21.04	730	45.11	294	27.69	120	18.13	0	0.00	17.71	62	6800	23200	49740	30528
1	301.52	11024.0	80	37.02	133	0	133	0	0	36	6.53	474	21.84	724	44.63	283	27.00	122	18.43	0	0.00	16.87	54	7200	24080	49200	29760
1	302.80	10984.4	80	108.65	140	0	140	0	0	32	5.83	470	21.39	732	45.56	286	27.22	121	18.28	0	0.00	14.81	52	6400	23500	50040	29904
1	301.06	11048.0	80	8.21	134	0	134	0	0	32	5.79	476	21.54	732	45.29	285	27.37	122	18.43	0	0.00	17.46	56	6400	23800	50040	30240
1	302.17	11024.4	80	227.34	136	0	136	0	0	42	7.62	478	21.88	718	43.81	287	26.69	134	20.24	0	0.00	17.54	55	8400	24120	48300	29424
1	302.03	11004.0	80	163.38	141	0	141	0	0	32	5.82	474	21.88	728	45.26	283	27.04	125	18.88	0	0.00	18.73	65	6400	24080	49800	29760
1	301.36	11017.2	80	294.90	138	0	138	0	0	38	6.90	472	21.97	718	44.17	284	26.97	117	17.67	0	0.00	16.48	51	7600	24200	48660	29712
12	303.67	10844.8	79	222.83	1357	0	1357	0	0	36	6.55	464	21.10	728	44.96	274	26.01	119	17.98	0	0.00	17.08	56	7200	23200	49440	28608
12	304.23	10966.8	80	94.57	1345	0	1345	0	0	36	6.57	478	22.49	720	44.64	278	26.30	133	20.09	0	0.00	18.54	63	7200	24660	48960	28848
12	302.66	10992.4	80	33.31	1337	0	1337	0	0	36	6.55	468	21.48	724	44.74	289	27.19	126	19.03	0	0.00	14.81	49	7200	23620	49200	29904
12	302.56	10980.0	78	125.58	1350	0	1350	0	0	34	6.18	472	21.79	726	44.99	285	26.83	123	18.58	0	0.00	15.23	51	6800	23980	49500	29520
12	303.34	10911.2	78	291.53	1366	0	1365	0	0	32	5.77	464	20.91	732	45.09	280	26.56	125	18.88	0	0.00	16.21	65	6400	23200	50040	29472
12	303.59	10955.2	78	243.84	1347	0	1347	0	0	34	6.15	466	21.07	730	44.97	284	26.86	121	18.28	0	0.00	15.46	51	6800	23300	49740	29712
12	303.03	10975.2	80	67.97	1383	0	1383	0	0	36	6.53	460	21.02	728	44.87	288	27.18	123	18.58	0	0.00	16.40	52	7200	23160	49440	29952
12	303.81	10998.4	80	78.25	1371	0	1371	0	0	30	5.45	470	21.36	734	45.77	287	27.40	125	18.88	0	0.00	16.06	49	6000	23500	50340	30144
12	303.72	10984.0	80	47.11	1345	0	1345	0	0	36	6.51	474	21.63	724	44.49	285	26.69	125	18.88	0	0.00	16.04	55	7200	23920	49200	29520
12	303.42	11003.2	80	118.79	1364	0	1364	0	0	34	6.15	478	22.16	722	44.55	283	26.66	131	19.79	0	0.00	16.83	62	6800	24500	49260	29472
36	317.74	10980.4	79	63.38	1396	0	1396	0	0	34	6.19	472	22.04	724	44.97	281	26.80	132	19.94	0	0.00	16.63	56	6800	24200	49380	29424
36	314.90	10949.2	79	181.69	1405	0	1405	0	0	32	5.73	474	21.76	724	44.38	279	26.18	128	19.34	0	0.00	17.15	52	6400	24300	49560	29232
36	312.70	10963.6	80	267.28	1388	0	1388	0	0	36	6.51	474	21.57	728	44.70	281	26.34	128	19.34	0	0.00	15.54	53	7200	23860	49440	29136
36	319.60	10969.6	80	19.86	1414	0	1414	0	0	40	7.22	460	20.75	724	44.05	290	26.93	124	18.73	0	0.00	16.52	55	8000	23000	48840	29856
36	314.11	10959.2	80	289.12	1376	0	1376	0	0	36	6.52	462	21.25	724	44.52	284	26.89	121	18.28	0	0.00	16.40	52	7200	23480	49200	29712
36	313.75	10924.8	80	163.05	1406	0	1406	0	0	36	6.50	450	20.79	724	44.39	288	26.89	119	17.98	0	0.00	16.19	49	7200	23040	49200	29808
36	311.88	10945.2	80	241.11	1379	0	1379	0	0	38	6.87	480	22.10	718	44.00	274	26.00	124	18.73	0	0.00	15.56	56	7600	24440	48660	28752
36	311.50	10951.6	80	78.39	1395	0	1395	0	0	40	7.22	476	21.67	720	43.84	280	26.06	119	17.98	0	0.00	17.31	53	8000	24020	48600	28896
36	313.40	10960.4	78	104.43	1395	0	1394	0	0	32	5.78	470	21.21	732	45.16	282	26.77	133	20.09	0	0.00	16.54	53	6400	23500	50040	29664
36	319.71	11005.6	80	3.15	1438	0	1438	0	0	36	6.49	482	22.30	716	43.89	282	26.46	122	18.43	0	0.00	16.42	50	7200	24760	48720	29376
36*	305.46	10946.0	80	165.94	1340	0	1340	0	0	38	6.94	464	21.20	726	44.89	285	26.97	121	18.28	0	0.00	18.56	67	7600	23200	49140	29520
36*	307.23	10943.2	80	278.69	1349	0	1349	0	0	32	5.85	472	21.71	732	45.73	279	26.71	137	20.69	0	0.00	16.62	53	6400	23760	50040	29232
36*	305.60	10905.6	80	249.93	1371	0	1371	0	0	40	7.34	472	22.04	716	44.34	279	26.28	117	17.67	0	0.00	16.10	55	8000	24040	48360	28656
36*	306.76	10963.6	80	29.44	1381	0	1381	0	0	36	6.57	468	21.54	724	44.88	283	27.01	125	18.88	0	0.00	15.60	54	7200	23620	49200	29616
36*	306.17	10844.8	79	223.38	1349	0	1349	0	0	36	6.64	464	21.39	728	45.59	274	26.38	119	17.98	0	0.00	17.08	56	7200	23200	49440	28608
36*	305.39	11006.8	80	16.35	1362	0	1362	0	0	34	6.18	476	21.77	730	45.19	284	26.86	127	19.18	0	0.00	16.35	55	6800	23960	49740	29568
36*	306.54	10924.8	80	181.04	1328	0	1328	0	0	36	6.59	450	21.09	724	45.04	288	27.28	119	17.98	0	0.00	16.19	49	7200	23040	49200	29808
36*	305.92	10962.8	80	62.70	1358	0	1358	0	0	32	5.84	478	22.20	724	45.21	280	26.75	134	20.24	0	0.00	20.10	55	6400	24340	49560	29328
36*	306.93	10964.4	80	301.39	1363	0	1363	0	0	32	5.84	474	22.56	716	44.76	278	26.84	129	19.49	0	0.00	15.92	55	6400	24740	49080	29424
36*	306.06	10978.0	80	13.34	1380	0	1380	0	0	34	6.19	472	22.04	722	44.87	282	26.89	126	19.03	0	0.00	16.35	67	6800	24200	49260	29520

Table D.19: Results of all runs made with GEANT2 network case 8, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	#10G	%10G	#40G	%40G	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.80	12716.4	80	76.22	162	0	162	0	0	46	7.23	402	16.45	786	46.57	340	29.74	115	21.74	0	0.00	13.44	54	9200	20920	59220	37824
1	301.77	12660.4	80	111.45	158	0	158	0	0	42	6.63	394	15.86	798	47.63	334	29.88	110	20.79	0	0.00	15.90	54	8400	20080	60300	37824
1	300.78	12740.0	80	251.63	166	0	166	0	0	48	7.54	400	15.70	796	46.81	348	29.95	116	21.93	0	0.00	16.08	56	9600	20000	59640	38160
1	301.44	12660.4	80	40.25	162	0	162	0	0	48	7.58	396	15.81	792	46.92	342	29.69	123	23.25	0	0.00	14.65	48	9600	20020	59400	37584
1	301.58	12621.6	80	239.99	160	0	160	0	0	46	7.29	404	17.00	778	46.54	325	29.17	117	22.12	0	0.00	15.19	55	9200	21460	58740	36816
1	302.41	12629.2	80	63.68	163	0	163	0	0	46	7.28	396	16.03	790	47.08	334	29.61	121	22.87	0	0.00	14.90	54	9200	20240	59460	37392
1	302.20	12668.4	80	301.00	159	0	159	0	0	48	7.58	404	16.25	792	46.89	337	29.29	120	22.68	0	0.00	12.83	53	9600	20580	59400	37104
1	301.75	12562.0	80	173.43	159	0	159	0	0	46	7.32	408	17.07	782	46.95	321	28.66	118	22.31	0	0.00	14.69	54	9200	21440	58980	36000
1	301.13	12731.2	80	99.25	156	0	156	0	0	46	7.23	412	16.70	786	46.52	338	29.56	123	23.25	0	0.00	13.81	48	9200	21260	59220	37632
1	302.67	12620.0	80	139.06	158	0	158	0	0	46	7.29	400	16.50	786	46.93	325	29.29	115	21.74	0	0.00	14.69	54	9200	20820	59220	36960
12	303.39	12503.2	80	199.46	1561	0	1561	0	0	46	7.25	400	16.27	786	46.64	319	28.32	119	22.50	0	0.00	15.31	52	9200	20660	59220	35952
12	302.89	12599.2	80	9.52	1513	0	1513	0	0	50	7.91	402	16.38	786	46.57	333	28.83	113	21.36	0	0.00	15.12	55	10000	20700	58860	36432
12	303.67	12649.6	80	153.85	1572	0	1572	0	0	48	7.58	406	16.32	792	46.88	331	29.05	116	21.93	0	0.00	14.37	55	9600	20680	59400	36816
12	302.67	12573.2	80	218.42	1522	0	1522	0	0	46	7.24	396	16.05	790	46.77	328	28.85	115	21.74	0	0.00	14.44	50	9200	20400	59460	36672
12	303.12	12616.0	80	168.23	1584	0	1584	1	0	46	7.21	400	16.67	778	46.05	328	28.98	117	22.12	0	0.00	14.31	54	9200	21260	58740	36960
12	303.44	12618.0	80	145.81	1605	0	1605	0	0	40	6.26	396	16.14	792	47.07	324	29.31	111	20.98	0	0.00	15.15	56	8000	20620	60120	37440
12	302.95	12599.6	80	181.54	1548	0	1548	0	0	46	7.22	388	15.35	798	47.03	339	29.26	108	20.42	0	0.00	14.94	57	9200	19560	59940	37296
12	303.14	12567.2	80	123.16	1553	0	1553	0	0	50	7.87	414	16.98	778	45.93	321	28.10	115	21.74	0	0.00	14.69	57	10000	21580	58380	35712
12	302.91	12535.2	80	208.28	1538	0	1538	0	0	46	7.27	394	16.39	782	46.62	324	28.80	117	22.12	0	0.00	14.87	59	9200	20740	58980	36432
12	302.84	12588.4	80	158.92	1532	0	1532	3	0	52	8.24	392	15.71	788	46.60	336	29.22	117	22.12	0	0.00	15.96	53	10400	19820	58800	36864
36	311.69	12564.0	80	300.85	1564	0	1564	0	0	48	7.49	396	15.92	788	46.18	326	28.48	120	22.68	0	0.00	14.00	42	9600	20400	59160	36480
36	312.55	12510.8	80	75.19	1633	0	1633	0	0	48	7.44	392	15.37	792	46.06	327	28.14	111	20.98	0	0.00	14.58	55	9600	19820	59400	36288
36	314.45	12562.0	80	217.03	1626	0	1626	0	0	46	7.20	408	16.78	782	46.15	321	28.17	118	22.31	0	0.00	14.69	54	9200	21440	58980	36000
36	313.08	12572.8	80	5.59	1616	0	1616	1	0	48	7.50	404	16.72	780	45.86	326	28.17	113	21.36	0	0.00	14.92	55	9600	21400	58680	36048
36	319.38	12583.2	80	221.21	1674	0	1674	0	0	48	7.49	396	15.92	788	46.18	331	28.62	109	20.60	0	0.00	15.69	55	9600	20400	59160	36672
36	316.29	12459.6	80	58.52	1628	0	1628	2	0	48	7.70	398	16.81	780	47.10	316	28.39	113	21.36	0	0.00	15.02	57	9600	20940	58680	35376
36	312.86	12632.0	80	150.93	1602	0	1602	0	0	48	7.53	398	15.79	792	46.61	335	29.19	112	21.17	0	0.00	14.79	57	9600	20120	59400	37200
36	319.36	12597.2	80	57.56	1658	0	1658	1	0	42	6.55	390	15.49	798	46.99	334	29.14	113	21.36	0	0.00	13.98	48	8400	19880	60300	37392
36	313.15	12544.0	80	235.36	1564	0	1564	0	0	50	7.83	404	16.12	790	46.29	320	28.01	121	22.87	0	0.00	15.25	55	10000	20580	59100	35760
36	313.83	12563.2	80	274.56	1648	0	1648	0	0	48	7.50	402	16.34	784	46.01	323	28.26	120	22.68	0	0.00	14.60	50	9600	20920	58920	36192
36*	308.35	12627.6	80	300.74	1542	0	1542	0	0	48	7.60	406	16.77	780	46.47	331	29.16	115	21.74	0	0.00	14.94	60	9600	21180	58680	36816
36*	305.56	12572.8	80	14.90	1566	0	1566	0	0	48	7.64	404	17.02	780	46.67	326	28.67	113	21.36	0	0.00	14.92	55	9600	21400	58680	36048
36*	306.23	12503.2	80	201.18	1549	0	1549	0	0	46	7.36	400	16.52	786	47.36	319	28.75	119	22.50	0	0.00	15.31	52	9200	20660	59220	35952
36*	304.71	12609.2	80	237.92	1572	0	1572	0	0	48	7.61	404	16.19	792	47.11	334	29.08	109	20.60	0	0.00	14.31	57	9600	20420	59400	36672
36*	305.85	12601.2	80	117.58	1531	0	1531	1	0	50	7.94	392	15.68	794	47.09	332	29.29	113	21.36	0	0.00	13.73	52	10000	19760	59340	36912
36*	305.99	12599.6	80	187.43	1585	0	1585	0	0	46	7.30	388	15.52	798	47.57	339	29.60	108	20.42	0	0.00	14.94	57	9200	19560	59940	37296
36*	305.85	12544.0	80	304.67	1581	0	1581	0	0	50	7.97	404	16.41	790	47.11	320	28.51	121	22.87	0	0.00	15.25	55	10000	20580	59100	35760
36*	304.84	12566.8	80	14.51	1588	0	1588	0	0	48	7.64	404	16.60	784	46.89	327	28.88	124	23.44	0	0.00	15.10	54	9600	20860	58920	36288
36*	305.93	12563.2	80	296.06	1571	0	1571	0	0	48	7.64	402	16.65	784	46.90	323	28.81	120	22.68	0	0.00	14.60	50	9600	20920	58920	36192
36*	305.15	12601.6	80	107.33	1564	0	1564	0	0	48	7.62	408	16.79	788	46.95	319	28.64	117	22.12	0	0.00	13.98	55	9600	21160	59160	36096

Table D.20: Results of all runs made with GEANT2 network case 9, in 300 seconds.

D.3 EON, Given 60 Seconds

Symbol	Name
$\#T$	Number of Threads
t_E	Time of Execution
C	Best Cost Solution found
CA	Highest Channel Assigned
t_{sol}	Found Solution Time
$\#i$	Number of Iterations
$\#IS$	Number of Invalid Solutions
$\#G_U$	Number of Greedy Solutions Unfeasible
$\#LS_U$	Number of Local Search Solutions Unfeasible
UD	Unfeasible Degree
$\#IM$	Number of Invert Multiplex used
C_{IM}	Cost % of Invert Multiplex
$\#MX$	Number of Muxponders placed
C_{MX}	Cost % of Muxponders
$\#TX$	Number of Transponders placed
C_{TX}	Cost % of Transponders
$\#3R$	Number of $3R$ regenerators placed
C_{3R}	Cost % of $3R$ regenerators
$\#10$	Number of Multi-Hop Grooming of $10Gb/s$
$\%10$	Traffic % of Multi-Hop Grooming of $10Gb/s$
$\#40$	Number of Multi-hop Grooming of $40Gb/s$
$\%40$	Traffic % of Multi-hop Grooming of $40Gb/s$
$\bar{m}F$	Average Fragmentation at Channel Assigned
MF	Max Fragmentation at Channel Assigned
C_{IM}	Cost of Invert Multiplexers
C_{MX}	Cost of Multiplexers
C_{TX}	Cost of Transponders
C_{3R}	Cost of $3R$ regenerators

Table D.21: Header symbols and their description.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.39	6921.6	57	55.57	2433	0	0	0	0	20	5.78	508	38.08	300	33.81	137	22.33	18	1.80	0	0.00	5.19	31	4000	26360	23400	15456
1	60.25	6960.0	58	34.65	2404	0	0	0	0	18	5.17	502	38.36	302	34.05	131	22.41	32	3.20	0	0.00	4.22	29	3600	26700	23700	15600
1	60.42	6926.8	58	6.99	2431	0	0	0	0	18	5.20	512	38.34	302	34.21	135	22.24	22	2.20	0	0.00	5.41	31	3600	26560	23700	15408
1	60.23	6999.2	62	52.21	2422	0	0	0	0	18	5.14	522	38.43	302	33.86	139	22.56	20	2.00	0	0.00	6.05	31	3600	26900	23700	15792
1	60.39	6975.2	65	16.88	2421	0	0	0	0	18	5.16	514	38.22	302	33.98	139	22.64	20	2.00	0	0.00	4.89	30	3600	26660	23700	15792
1	60.22	6976.8	55	30.09	2431	0	0	0	0	18	5.16	514	37.75	302	33.97	147	23.12	16	1.60	0	0.00	4.65	27	3600	26340	23700	16128
1	60.39	6965.2	63	32.99	2438	0	0	0	0	16	4.59	506	37.93	304	34.46	140	23.02	19	1.90	0	0.00	5.89	31	3200	26420	24000	16032
1	60.23	6966.4	56	39.34	2429	0	0	0	0	20	5.74	508	38.07	300	33.59	140	22.60	19	1.90	0	0.00	5.41	33	4000	26520	23400	15744
1	60.40	6966.0	59	27.91	2437	0	0	0	0	18	5.17	508	38.07	302	34.02	138	22.74	22	2.20	0	0.00	5.49	33	3600	26520	23700	15840
1	60.22	6974.4	59	6.55	2426	0	0	0	0	20	5.74	508	37.80	300	33.55	144	22.92	20	2.00	0	0.00	5.22	31	4000	26360	23400	15984
12	60.25	6914.4	61	44.48	24249	0	0	0	0	18	5.15	506	38.05	302	33.92	132	21.85	20	2.00	0	0.00	5.27	33	3600	26580	23700	15264
12	60.43	6974.8	61	3.46	22998	0	0	0	0	18	5.14	512	37.96	302	33.87	137	22.70	26	2.60	0	0.00	5.43	31	3600	26560	23700	15888
12	60.26	6932.8	56	26.16	23968	0	0	0	0	22	6.29	506	37.78	298	33.03	135	22.03	20	2.00	0	0.00	4.14	31	4400	26420	23100	15408
12	60.42	6940.8	56	18.63	23585	0	0	0	0	16	4.57	512	37.91	304	34.25	136	22.33	20	2.00	0	0.00	4.95	26	3200	26560	24000	15648
12	60.26	6956.4	57	23.28	24364	0	0	0	0	16	4.57	502	37.70	304	34.30	138	22.84	17	1.70	0	0.00	6.05	27	3200	26380	24000	15984
12	60.43	6946.0	62	33.03	24018	0	0	0	0	22	6.32	508	37.87	298	33.19	137	22.41	19	1.90	0	0.00	4.78	26	4400	26360	23100	15600
12	60.25	6946.4	64	19.23	24049	0	0	0	0	16	4.58	516	37.62	304	34.36	144	22.88	19	1.90	0	0.00	5.84	29	3200	26280	24000	15984
12	60.43	6952.0	58	35.80	23800	0	0	0	0	18	5.15	510	38.11	302	33.93	137	22.34	15	1.50	0	0.00	5.05	33	3600	26620	23700	15600
12	60.29	6956.0	64	30.83	24578	0	0	0	0	18	5.14	514	38.10	302	33.87	137	22.29	21	2.10	0	0.00	6.49	33	3600	26660	23700	15600
12	60.40	6957.6	58	3.32	25004	0	0	0	0	16	4.59	500	37.91	304	34.41	136	22.85	22	2.20	0	0.00	5.22	31	3200	26440	24000	15936
36	66.46	6974.4	64	19.09	27867	0	0	0	0	20	5.72	508	37.69	300	33.46	144	22.85	18	1.80	0	0.00	6.22	30	4000	26360	23400	15984
36	66.74	6938.4	64	43.62	28003	0	0	0	0	20	5.71	504	37.78	300	33.39	136	22.12	20	2.00	0	0.00	7.11	32	4000	26480	23400	15504
36	66.58	6948.4	58	47.99	27976	0	0	0	0	20	5.72	506	37.98	300	33.43	136	22.15	18	1.80	0	0.00	5.35	22	4000	26580	23400	15504
36	77.80	6951.2	59	47.03	32114	0	0	0	0	16	4.57	508	37.89	304	34.29	139	22.56	20	2.00	0	0.00	5.70	33	3200	26520	24000	15792
36	76.72	6970.8	59	6.74	31579	0	0	0	0	20	5.73	514	38.19	300	33.52	139	22.41	18	1.80	0	0.00	5.00	32	4000	26660	23400	15648
36	73.16	6935.2	58	16.46	30456	0	0	0	0	16	4.56	508	37.56	304	34.20	136	22.50	19	1.90	0	0.00	4.51	32	3200	26360	24000	15792
36	72.10	6930.0	65	32.25	30081	0	0	0	0	18	5.16	512	37.85	302	33.98	137	22.37	21	2.10	0	0.00	6.05	31	3600	26400	23700	15600
36	67.81	6947.6	63	58.69	28543	0	0	0	0	16	4.59	522	38.13	304	34.43	138	22.51	21	2.10	0	0.00	6.19	34	3200	26580	24000	15696
36	67.25	6959.6	61	53.21	28114	0	0	0	0	18	5.15	508	37.71	302	33.90	139	22.80	18	1.80	0	0.00	5.78	31	3600	26360	23700	15936
36	68.52	6948.8	59	47.50	28228	0	0	0	0	18	5.15	510	37.61	302	33.89	140	22.72	18	1.80	0	0.00	5.19	31	3600	26300	23700	15888
36*	61.11	6955.6	55	19.19	25551	0	0	0	0	18	5.18	512	38.19	302	34.07	138	22.57	24	2.40	0	0.00	4.97	30	3600	26560	23700	15696
36*	61.35	6934.0	55	9.64	25869	0	0	0	0	18	5.19	500	38.13	302	34.18	134	22.50	16	1.60	0	0.00	4.70	27	3600	26440	23700	15600
36*	61.11	6934.0	56	8.78	25870	0	0	0	0	20	5.77	514	38.68	300	33.75	135	21.81	25	2.50	0	0.00	4.54	31	4000	26820	23400	15120
36*	61.09	6951.2	60	39.83	25760	0	0	0	0	20	5.75	512	38.21	300	33.66	138	22.37	21	2.10	0	0.00	4.49	32	4000	26560	23400	15552
36*	61.06	6949.2	58	9.03	25311	0	0	0	0	20	5.76	510	37.85	300	33.67	142	22.72	14	1.40	0	0.00	4.54	31	4000	26300	23400	15792
36*	77.38	6962.0	62	16.30	32691	0	0	0	0	22	6.32	516	38.44	298	33.18	139	22.06	23	2.30	0	0.00	5.49	32	4400	26760	23100	15360
36*	61.17	6957.6	58	15.76	25509	0	0	0	0	16	4.60	500	38.00	304	34.49	136	22.90	22	2.20	0	0.00	5.22	31	3200	26440	24000	15936
36*	60.98	6959.6	58	45.47	25875	0	0	0	0	16	4.60	510	38.02	304	34.48	139	22.90	23	2.30	0	0.00	4.97	31	3200	26460	24000	15936
36*	61.37	6961.6	55	54.24	24124	0	0	0	0	20	5.75	516	39.30	294	33.10	136	21.86	17	1.70	0	0.00	4.22	31	4000	27360	23040	15216
36*	61.01	6972.4	59	1.48	25845	0	0	0	0	18	5.16	516	37.92	302	33.99	141	22.92	18	1.80	0	0.00	6.24	30	3600	26440	23700	15984

Table D.22: Results of all runs made with EON network case 1, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.25	8047.2	53	2.65	2739	0	0	0	0	24	5.96	266	19.09	536	48.46	189	26.48	18	3.60	0	0.00	5.59	22	4800	15360	39000	21312
1	60.40	8064.0	63	25.79	2752	0	0	0	0	20	4.96	248	17.36	560	50.60	199	27.08	16	3.20	0	0.00	6.49	26	4000	14000	40800	21840
1	60.25	8025.6	60	57.50	2748	0	0	0	0	24	5.98	256	18.09	548	49.49	191	26.44	22	4.40	0	0.00	5.41	23	4800	14520	39720	21216
1	60.42	8056.8	63	9.38	2745	0	0	0	0	22	5.46	242	17.40	558	50.27	197	26.87	17	3.40	0	0.00	6.22	29	4400	14020	40500	21648
1	60.25	8068.8	61	45.12	2735	0	0	0	0	24	5.95	262	19.19	536	48.33	187	26.53	15	3.00	0	0.00	7.24	25	4800	15480	39000	21408
1	60.40	8073.2	58	57.39	2706	0	0	0	0	24	5.95	250	17.27	556	49.79	197	26.99	17	3.40	0	0.00	5.32	27	4800	13940	40200	21792
1	60.23	8059.6	58	37.75	2740	0	0	0	0	22	5.46	254	18.56	546	49.36	189	26.62	18	3.60	0	0.00	6.51	23	4400	14960	39780	21456
1	60.40	8058.8	60	23.56	2746	0	0	0	0	22	5.46	248	18.32	550	49.66	190	26.56	16	3.20	0	0.00	5.08	24	4400	14760	40020	21408
1	60.23	8030.8	49	39.67	2752	0	0	0	0	24	5.98	246	17.31	556	50.06	193	26.66	18	3.60	0	0.00	7.30	24	4800	13900	40200	21408
1	60.39	8041.6	56	26.21	2731	0	0	0	0	22	5.47	250	18.08	550	49.77	192	26.68	16	3.20	0	0.00	6.24	22	4400	14540	40020	21456
12	60.43	8014.8	55	32.54	22970	0	0	0	0	22	5.49	244	18.17	550	49.93	189	26.41	15	3.00	0	0.00	5.84	23	4400	14560	40020	21168
12	60.26	8052.4	52	29.09	23328	0	0	0	0	24	5.94	248	18.55	544	48.89	187	26.33	20	4.00	0	0.00	5.76	23	4800	14980	39480	21264
12	60.45	7993.2	65	20.16	24257	0	0	0	0	22	5.45	248	17.87	550	49.53	188	26.08	17	3.40	0	0.00	5.22	22	4400	14440	40020	21072
12	60.28	8052.4	68	58.11	25740	0	0	0	0	22	5.46	252	17.23	558	50.29	198	27.00	17	3.40	0	0.00	7.03	27	4400	13880	40500	21744
12	60.47	8030.4	51	19.98	24525	0	1	0	0	22	5.46	242	18.14	550	49.65	187	26.38	17	3.40	0	0.00	6.22	22	4400	14620	40020	21264
12	60.29	8046.0	47	24.96	23962	0	0	0	0	22	5.45	242	18.19	546	49.29	186	26.76	15	3.00	0	0.00	5.89	23	4400	14680	39780	21600
12	60.47	8041.6	57	35.02	22679	0	0	0	0	24	5.94	260	17.28	556	49.76	198	26.56	19	3.80	0	0.00	6.08	19	4800	13960	40200	21456
12	60.28	8028.4	51	21.58	24147	0	0	0	0	24	5.93	248	18.52	544	48.81	183	25.99	19	3.80	0	0.00	7.16	25	4800	14980	39480	21024
12	60.43	8009.6	63	44.66	24612	0	0	0	0	24	5.96	252	17.25	556	49.95	194	26.36	21	4.20	0	0.00	5.19	21	4800	13880	40200	21216
12	60.26	8027.6	58	39.89	24632	0	0	0	0	22	5.44	252	18.09	550	49.46	191	26.22	18	3.60	0	0.00	5.73	22	4400	14640	40020	21216
36	71.65	8030.0	61	52.54	29867	0	0	0	0	24	5.92	262	18.09	548	49.01	193	26.06	22	4.40	0	0.00	6.59	25	4800	14660	39720	21120
36	74.82	8028.4	65	46.08	30538	0	1	0	0	24	5.92	242	17.28	556	49.55	190	26.21	16	3.20	0	0.00	5.89	24	4800	14020	40200	21264
36	67.10	8023.6	53	47.28	26588	0	0	0	0	22	5.42	252	17.10	558	49.90	195	26.44	19	3.80	0	0.00	5.57	26	4400	13880	40500	21456
36	65.96	8037.6	60	34.76	28147	0	0	0	0	24	5.90	252	18.01	548	48.86	188	26.10	22	4.40	0	0.00	6.32	24	4800	14640	39720	21216
36	68.80	8028.0	53	1.73	27821	0	0	0	0	24	5.92	246	18.34	544	48.66	187	26.03	19	3.80	0	0.00	7.32	21	4800	14880	39480	21120
36	76.05	8037.6	59	43.90	31735	0	0	0	0	24	5.91	256	17.14	556	49.51	195	26.42	19	3.80	0	0.00	6.86	23	4800	13920	40200	21456
36	76.91	8040.8	57	13.78	30074	0	0	0	0	22	5.46	254	18.10	550	49.69	193	26.58	15	3.00	0	0.00	6.68	23	4400	14580	40020	21408
36	74.54	7997.2	68	17.86	31066	0	0	0	0	22	5.46	248	17.36	558	50.21	191	26.13	23	4.60	0	0.00	5.73	27	4400	14000	40500	21072
36	74.37	8020.4	48	42.60	31388	0	0	0	0	24	5.92	254	17.79	548	49.00	190	26.23	18	3.60	0	0.00	6.24	24	4800	14420	39720	21264
36	68.80	8018.8	55	48.25	27664	0	0	0	0	24	5.91	246	17.84	548	48.87	186	26.05	20	4.00	0	0.00	6.08	23	4800	14500	39720	21168
36*	60.84	8032.0	60	17.66	26284	0	0	0	0	22	5.48	252	18.70	546	49.53	187	26.29	14	2.80	0	0.00	6.27	24	4400	15020	39780	21120
36*	61.11	8038.4	56	54.59	27272	0	0	0	0	20	4.98	256	17.52	560	50.76	197	26.75	17	3.40	0	0.00	6.57	23	4000	14080	40800	21504
36*	68.64	8035.2	62	28.25	24854	0	0	0	0	26	6.47	260	19.14	534	48.16	185	26.22	19	3.80	0	0.00	5.81	24	5200	15380	38700	21072
36*	61.25	8015.2	57	16.47	27205	0	1	0	0	24	5.99	248	17.27	556	50.15	195	26.59	18	3.60	0	0.00	5.49	24	4800	13840	40200	21312
36*	60.90	8046.0	47	18.11	25588	0	0	0	0	22	5.47	242	18.25	546	49.44	186	26.85	15	3.00	0	0.00	5.89	23	4400	14680	39780	21600
36*	61.28	8041.2	59	49.59	27187	0	0	0	0	22	5.47	250	18.55	546	49.47	186	26.50	18	3.60	0	0.00	6.57	24	4400	14920	39780	21312
36*	61.01	8036.4	49	0.86	26784	0	0	0	0	22	5.48	248	17.97	550	49.80	191	26.76	15	3.00	0	0.00	5.22	22	4400	14440	40020	21504
36*	61.28	7970.8	53	28.44	24841	0	0	0	0	22	5.52	252	17.41	558	50.81	191	26.26	18	3.60	0	0.00	6.32	24	4400	13880	40500	20928
36*	60.92	8010.8	55	24.60	23930	0	1	0	0	22	5.49	244	17.23	558	50.56	193	26.72	18	3.60	0	0.00	6.70	25	4400	13800	40500	21408
36*	75.35	8023.6	53	31.87	27259	0	0	0	0	22	5.48	252	17.30	558	50.48	195	26.74	19	3.80	0	0.00	5.57	26	4400	13880	40500	21456

Table D.23: Results of all runs made with EON network case 2, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	#10G	%10G	#40G	%40G	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.23	8060.8	51	4.02	3342	0	0	0	0	12	2.98	188	12.85	648	64.76	124	19.41	19	5.43	0	0.00	3.92	28	2400	10360	52200	15648
1	60.40	8065.2	50	23.59	3368	0	0	0	0	12	2.98	178	12.42	648	64.72	128	19.88	17	4.86	0	0.00	4.41	26	2400	10020	52200	16032
1	60.23	8047.6	50	19.64	3364	0	0	0	0	26	6.46	180	12.38	634	62.25	127	18.91	22	6.29	0	0.00	5.16	33	5200	9960	50100	15216
1	60.42	8021.2	51	49.92	3353	0	0	0	0	12	2.99	186	13.14	640	64.48	123	19.39	16	4.57	0	0.00	5.30	38	2400	10540	51720	15552
1	60.23	8061.2	51	53.63	3381	0	0	0	0	26	6.45	192	12.70	634	62.15	121	18.70	19	5.43	0	0.00	4.03	26	5200	10240	50100	15072
1	60.43	8038.8	52	24.38	3303	0	0	0	0	12	2.99	182	12.32	648	64.94	128	19.76	17	4.86	0	0.00	3.89	24	2400	9900	52200	15888
1	60.25	8059.6	52	46.43	3331	0	0	0	0	16	3.97	178	12.23	644	64.02	127	19.77	16	4.57	0	0.00	5.05	22	3200	9860	51600	15936
1	60.43	8076.4	50	15.07	3303	0	0	0	0	16	3.96	186	13.25	636	63.30	122	19.49	16	4.57	0	0.00	3.57	20	3200	10700	51120	15744
1	60.25	8009.6	56	2.93	3352	0	0	0	0	12	3.00	184	13.43	640	64.57	118	19.00	22	6.29	0	0.00	4.05	40	2400	10760	51720	15216
1	60.42	8006.8	49	2.62	3348	0	0	0	0	16	4.00	186	12.61	644	64.45	119	18.94	16	4.57	0	0.00	4.95	24	3200	10100	51600	15168
12	60.45	8016.8	49	11.09	31196	0	0	0	0	20	4.96	192	12.70	640	63.27	118	18.52	29	8.29	0	0.00	5.11	36	4000	10240	51000	14928
12	60.47	8011.2	51	0.11	33344	0	0	0	0	12	2.98	180	12.36	648	64.80	123	19.31	19	5.43	0	0.00	4.54	36	2400	9960	52200	15552
12	60.26	8024.8	52	31.39	33905	0	0	0	0	12	2.97	184	12.38	648	64.63	124	19.38	19	5.43	0	0.00	4.68	38	2400	10000	52200	15648
12	60.45	8029.2	51	6.07	32820	0	0	0	0	12	2.99	190	12.63	648	65.01	120	19.37	20	5.71	0	0.00	4.43	39	2400	10140	52200	15552
12	60.28	8021.2	51	36.26	33889	0	0	0	0	12	2.98	182	12.50	648	64.85	123	19.32	15	4.29	0	0.00	4.92	33	2400	10060	52200	15552
12	60.45	8029.6	51	20.01	32797	0	0	0	0	12	2.99	184	12.45	648	65.01	126	19.55	24	6.86	0	0.00	4.54	28	2400	10000	52200	15696
12	60.25	8002.0	51	4.18	33844	0	0	0	0	12	2.99	190	12.84	648	65.08	120	18.85	19	5.43	0	0.00	4.16	35	2400	10300	52200	15120
12	60.47	8040.8	49	32.82	34351	0	0	0	0	18	4.45	186	12.48	642	63.39	126	19.04	15	4.29	0	0.00	3.89	34	3600	10100	51300	15408
12	60.28	8037.6	51	28.50	32536	0	0	0	0	12	2.97	192	12.46	648	64.54	126	19.41	21	6.00	0	0.00	4.03	26	2400	10080	52200	15696
12	60.45	8025.6	50	45.46	33289	0	0	0	0	12	2.98	188	12.65	648	64.75	122	19.17	17	4.86	0	0.00	4.19	37	2400	10200	52200	15456
36	71.95	8021.2	51	7.22	41855	0	0	0	0	12	2.96	182	12.39	648	64.30	123	19.16	18	5.14	0	0.00	4.27	34	2400	10060	52200	15552
36	66.78	8029.2	51	12.48	39102	0	0	0	0	12	2.97	190	12.56	648	64.63	123	19.26	20	5.71	0	0.00	5.00	37	2400	10140	52200	15552
36	65.83	8001.6	50	31.57	38230	0	0	0	0	12	3.00	180	12.45	648	65.24	122	19.32	20	5.71	0	0.00	4.59	36	2400	9960	52200	15456
36	75.35	8022.4	50	36.88	43494	0	0	0	0	16	3.98	176	12.33	644	64.12	121	19.27	17	4.86	0	0.00	4.35	39	3200	9920	51600	15504
36	70.06	8009.2	52	37.38	40599	0	0	0	0	12	2.97	194	12.58	648	64.50	122	18.92	21	6.00	0	0.00	4.22	27	2400	10180	52200	15312
36	76.67	8015.6	50	56.35	43470	0	0	0	0	16	3.95	190	12.50	644	63.61	121	18.76	17	4.86	0	0.00	3.81	20	3200	10140	51600	15216
36	74.38	8018.8	57	0.64	42161	0	0	0	0	22	5.47	184	12.63	638	63.02	118	18.56	22	6.29	0	0.00	5.19	35	4400	10160	50700	14928
36	80.39	8045.2	51	4.10	44722	0	0	0	0	16	3.97	186	12.53	644	64.03	126	19.30	17	4.86	0	0.00	5.46	31	3200	10100	51600	15552
36	76.55	8030.0	51	59.80	43765	0	0	0	0	12	2.96	186	12.45	648	64.33	125	19.23	23	6.57	0	0.00	5.49	41	2400	10100	52200	15600
36	68.53	8003.6	50	35.18	40055	0	0	0	0	18	4.46	184	12.59	642	63.59	123	18.56	22	6.29	0	0.00	4.32	33	3600	10160	51300	14976
36*	60.92	8048.8	50	53.16	35443	0	0	0	0	24	5.96	180	12.57	636	62.62	122	18.85	18	5.14	0	0.00	4.35	27	4800	10120	50400	15168
36*	61.32	8006.8	49	2.82	35997	0	0	0	0	16	4.00	186	12.61	644	64.45	119	18.94	16	4.57	0	0.00	4.95	24	3200	10100	51600	15168
36*	65.71	7995.2	51	59.11	38648	0	0	0	0	16	4.00	176	12.61	644	64.54	118	18.85	19	5.43	0	0.00	4.57	33	3200	10080	51600	15072
36*	72.37	8012.0	50	11.34	36046	0	0	0	0	12	3.00	184	12.68	648	65.15	121	19.17	24	6.86	0	0.00	3.41	27	2400	10160	52200	15360
36*	74.04	8018.4	51	14.12	40886	0	0	0	0	12	2.99	192	12.57	648	65.10	124	19.34	22	6.29	0	0.00	4.08	35	2400	10080	52200	15504
36*	61.18	8002.0	51	29.08	35188	0	0	0	0	12	3.00	190	12.87	648	65.23	120	18.90	19	5.43	0	0.00	4.16	35	2400	10300	52200	15120
36*	61.09	8037.6	52	45.82	34915	0	0	0	0	12	2.99	184	12.84	648	64.94	122	19.23	20	5.71	0	0.00	3.62	24	2400	10320	52200	15456
36*	60.75	8017.6	51	28.11	35679	0	0	0	0	12	2.99	188	12.32	648	65.11	126	19.58	21	6.00	0	0.00	4.97	36	2400	9880	52200	15696
36*	61.11	8029.2	51	10.41	34252	0	0	0	0	12	2.99	190	12.63	648	65.01	123	19.37	20	5.71	0	0.00	5.00	37	2400	10140	52200	15552
36*	61.28	8006.4	51	9.97	35466	0	0	0	0	16	4.00	184	12.49	644	64.45	120	19.06	21	6.00	0	0.00	4.89	33	3200	10000	51600	15264

Table D.24: Results of all runs made with EON network case 3, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.50	8697.6	65	20.67	1211	0	0	0	0	24	5.52	636	38.22	376	33.80	175	22.46	36	2.88	0	0.00	5.19	26	4800	33240	29400	19536
1	60.33	8665.2	65	21.20	1193	0	3	0	0	20	4.62	646	38.38	380	34.62	175	22.38	31	2.48	0	0.00	7.97	33	4000	33260	30000	19392
1	60.50	8690.8	64	55.89	1196	0	4	0	0	18	4.14	640	38.29	382	34.86	171	22.70	34	2.72	0	0.00	8.16	34	3600	33280	30300	19728
1	60.33	8645.6	70	33.24	1171	0	3	0	0	26	6.01	646	38.29	374	33.66	176	22.04	35	2.80	0	0.00	10.30	49	5200	33100	29100	19056
1	60.54	8636.4	66	11.19	1185	0	3	0	0	20	4.63	646	38.51	380	34.74	169	22.12	32	2.56	0	0.00	8.38	43	4000	33260	30000	19104
1	60.28	8684.8	65	52.28	1190	0	2	0	0	20	4.61	632	38.41	380	34.54	173	22.44	34	2.72	0	0.00	6.22	30	4000	33360	30000	19488
1	60.51	8655.6	68	5.51	1190	0	1	0	0	24	5.55	642	38.19	376	33.97	171	22.29	27	2.16	0	0.00	8.57	43	4800	33060	29400	19296
1	60.31	8672.4	65	46.41	1193	0	0	0	0	18	4.15	644	38.05	382	34.94	178	22.86	31	2.48	0	0.00	7.59	35	3600	33000	30300	19824
1	60.51	8656.4	65	54.60	1228	0	4	0	0	20	4.62	642	38.38	380	34.66	173	22.35	33	2.64	0	0.00	7.16	43	4000	33220	30000	19344
1	60.31	8680.8	65	41.25	1213	0	5	0	0	20	4.61	644	38.38	380	34.56	170	22.45	34	2.72	0	0.00	7.62	41	4000	33320	30000	19488
12	60.36	8663.6	65	16.33	12028	0	24	0	0	20	4.62	638	38.48	380	34.62	168	22.27	35	2.80	0	0.00	6.78	35	4000	33340	30000	19296
12	60.56	8652.8	65	34.35	11314	0	30	0	0	20	4.60	648	38.54	380	34.50	168	21.86	37	2.96	0	0.00	7.84	40	4000	33520	30000	19008
12	60.36	8665.2	64	45.49	12463	0	29	0	0	20	4.61	638	38.09	380	34.61	176	22.65	31	2.48	0	0.00	6.92	32	4000	33020	30000	19632
12	60.54	8650.8	65	36.25	12364	0	27	0	0	22	5.06	644	38.13	378	34.15	172	22.13	39	3.12	0	0.00	6.84	38	4400	33160	29700	19248
12	60.36	8624.8	65	36.13	12539	0	24	0	0	20	4.60	636	38.23	380	34.51	165	21.86	31	2.48	0	0.00	5.92	28	4000	33240	30000	19008
12	60.62	8666.0	68	13.40	12323	0	32	0	0	28	6.46	642	38.68	372	33.21	168	21.59	37	2.96	0	0.00	8.68	46	5600	33540	28800	18720
12	60.31	8643.2	66	29.89	12198	0	32	0	0	22	5.07	646	38.54	378	34.25	170	21.81	30	2.40	0	0.00	7.65	36	4400	33420	29700	18912
12	60.51	8650.8	65	44.01	12086	0	29	0	0	20	4.61	638	38.10	380	34.61	173	22.48	30	2.40	0	0.00	7.14	46	4000	33020	30000	19488
12	60.33	8638.0	65	19.78	12205	0	27	0	0	20	4.60	646	38.42	380	34.48	169	21.79	37	2.96	0	0.00	8.19	27	4000	33420	30000	18960
12	60.56	8645.6	65	8.69	12614	0	41	0	0	24	5.54	640	38.59	376	33.92	166	21.71	33	2.64	0	0.00	8.35	33	4800	33440	29400	18816
36	77.11	8652.0	64	11.53	16473	0	39	0	0	18	4.15	638	38.24	382	34.92	171	22.41	33	2.64	0	0.00	7.22	34	3600	33180	30300	19440
36	71.98	8664.0	63	15.29	15205	0	27	0	0	24	5.51	620	38.12	376	33.72	167	22.02	37	2.96	0	0.00	8.19	40	4800	33240	29400	19200
36	66.88	8636.4	66	55.15	14083	0	24	0	0	22	5.05	652	38.31	378	34.07	171	21.64	34	2.72	0	0.00	6.49	49	4400	33400	29700	18864
36	68.20	8658.4	64	21.34	14235	0	33	0	0	20	4.58	636	38.08	380	34.37	173	22.16	37	2.96	0	0.00	6.51	33	4000	33240	30000	19344
36	77.19	8662.4	64	11.39	15903	0	28	0	0	20	4.60	640	38.25	380	34.48	170	22.23	28	2.24	0	0.00	7.65	40	4000	33280	30000	19344
36	77.97	8627.2	65	24.06	16214	0	43	0	0	20	4.62	640	38.22	380	34.62	168	22.10	31	2.48	0	0.00	7.54	37	4000	33120	30000	19152
36	71.53	8656.8	67	43.70	14901	0	45	0	0	24	5.53	632	38.43	376	33.87	165	21.90	35	2.80	0	0.00	6.49	32	4800	33360	29400	19008
36	69.50	8628.0	65	55.63	14665	0	34	0	0	22	5.06	642	38.17	378	34.13	169	21.79	29	2.32	0	0.00	7.16	29	4400	33220	29700	18960
36	71.73	8642.8	65	58.66	15025	0	38	0	0	20	4.59	638	38.09	380	34.44	172	22.10	31	2.48	0	0.00	6.57	36	4000	33180	30000	19248
36	66.16	8636.4	66	12.81	13964	0	27	0	0	20	4.60	646	38.28	380	34.53	169	21.99	32	2.56	0	0.00	8.38	43	4000	33260	30000	19104
36*	61.34	8664.4	65	4.17	12535	0	23	0	0	22	5.08	640	38.04	378	34.28	174	22.60	34	2.72	0	0.00	7.38	32	4400	32960	29700	19584
36*	61.09	8638.8	69	7.50	13098	0	25	0	0	26	6.02	636	38.29	374	33.69	174	22.00	29	2.32	0	0.00	8.30	43	5200	33080	29100	19008
36*	61.32	8648.4	65	21.53	12662	0	29	0	0	24	5.55	638	38.37	376	33.99	169	22.09	31	2.48	0	0.00	6.65	36	4800	33180	29400	19104
36*	61.11	8656.8	65	43.20	12888	0	33	0	0	22	5.08	642	38.37	378	34.31	175	22.23	35	2.80	0	0.00	7.78	43	4400	33220	29700	19248
36*	61.23	8639.2	63	11.64	12600	0	32	0	0	20	4.63	636	38.48	380	34.73	171	22.17	43	3.44	0	0.00	6.54	39	4000	33240	30000	19152
36*	61.00	8666.0	67	9.13	12805	0	31	0	0	24	5.54	638	38.10	376	33.93	177	22.43	29	2.32	0	0.00	7.19	45	4800	33020	29400	19440
36*	61.25	8645.6	65	50.36	13047	0	44	0	0	24	5.55	640	38.68	376	34.01	166	21.76	33	2.64	0	0.00	8.35	33	4800	33440	29400	18816
36*	61.39	8660.8	65	27.18	12953	0	31	0	0	22	5.08	646	38.40	378	34.29	175	22.22	34	2.72	0	0.00	5.59	38	4400	33260	29700	19248
36*	67.17	8676.0	62	25.04	12932	0	33	0	0	18	4.15	638	38.24	382	34.92	175	22.68	28	2.24	0	0.00	6.30	28	3600	33180	30300	19680
36*	61.06	8653.2	75	6.37	12809	0	26	0	0	20	4.62	634	38.30	380	34.67	169	22.41	34	2.72	0	0.00	6.41	31	4000	33140	30000	19392

Table D.25: Results of all runs made with EON network case 4, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
#T	t_E	C	CA	t_{sol}	#i	#IS	#G_U	#LS_U	UD	#IM	C_{IM}	#MX	C_{MX}	#TX	C_{TX}	#$3R$	C_{3R}	#$10G$	%$10G$	#$40G$	%$40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.57	9791.6	80	3.95	920	0	920	50	0	26	5.31	328	21.06	666	50.00	190	23.63	36	5.76	0	0.00	9.86	42	5200	20620	48960	23136
1	60.32	9811.2	80	54.71	947	0	947	51	0	26	5.30	338	20.87	666	49.90	195	23.92	39	6.24	0	0.00	11.08	39	5200	20480	48960	23472
1	60.54	9828.0	80	26.80	942	0	942	39	0	20	4.07	336	21.51	664	50.24	192	24.18	38	6.08	0	0.00	7.97	32	4000	21140	49380	23760
1	60.28	9825.6	80	30.08	930	0	930	39	0	26	5.29	330	21.09	666	49.83	191	23.79	30	4.80	0	0.00	10.43	35	5200	20720	48960	23376
1	60.54	9828.0	79	10.05	944	0	944	51	0	28	5.70	332	20.86	664	49.51	197	23.93	30	4.80	0	0.00	9.30	31	5600	20500	48660	23520
1	60.29	9828.0	80	23.74	951	0	951	40	0	26	5.29	318	20.96	666	49.82	194	23.93	25	4.00	0	0.00	10.46	40	5200	20600	48960	23520
1	60.54	9803.2	79	51.79	920	0	920	41	0	28	5.71	320	20.95	664	49.64	191	23.70	32	5.12	0	0.00	10.65	37	5600	20540	48660	23232
1	60.54	9802.4	78	27.35	917	0	917	34	0	22	4.49	326	21.55	662	50.07	190	23.90	35	5.60	0	0.00	8.30	32	4400	21120	49080	23424
1	60.34	9834.4	80	40.79	936	0	936	45	0	26	5.29	310	20.87	666	49.78	194	24.06	29	4.64	0	0.00	10.00	37	5200	20520	48960	23664
1	60.51	9799.2	77	17.88	929	0	929	41	0	20	4.08	320	21.57	664	50.39	186	23.95	36	5.76	0	0.00	9.00	32	4000	21140	49380	23472
12	60.61	9776.4	80	10.45	9655	0	9655	401	0	26	5.31	324	20.83	666	49.95	192	23.65	34	5.44	0	0.00	10.19	38	5200	20420	48960	23184
12	60.40	9718.4	80	14.55	9610	0	9610	389	0	22	4.49	326	20.93	670	50.54	184	23.15	33	5.28	0	0.00	10.22	39	4400	20520	49560	22704
12	60.62	9775.6	80	11.25	9707	0	9707	397	0	26	5.30	328	20.86	666	49.93	193	23.59	32	5.12	0	0.00	9.65	36	5200	20460	48960	23136
12	60.37	9778.0	80	57.53	9754	0	9753	415	0	24	4.88	322	21.29	660	49.64	190	23.69	28	4.48	0	0.00	9.22	35	4800	20920	48780	23280
12	60.64	9793.6	80	57.85	9716	0	9716	406	0	24	4.89	324	21.15	668	50.23	193	23.59	35	5.60	0	0.00	8.97	30	4800	20740	49260	23136
12	60.37	9785.2	80	5.34	9724	0	9724	417	0	22	4.47	324	21.24	670	50.36	187	23.36	36	5.76	0	0.00	9.89	35	4400	20900	49560	22992
12	60.64	9781.6	80	50.56	9517	0	9517	402	0	22	4.47	334	21.53	662	49.85	187	23.50	36	5.76	0	0.00	10.00	33	4400	21200	49080	23136
12	60.36	9754.4	80	43.98	9901	0	9901	418	0	24	4.89	328	21.19	668	50.22	190	23.15	31	4.96	0	0.00	9.38	37	4800	20780	49260	22704
12	60.62	9784.0	80	53.35	9610	0	9610	372	0	24	4.89	328	21.64	660	49.73	192	23.49	40	6.40	0	0.00	9.11	36	4800	21220	48780	23040
12	60.36	9795.2	80	2.79	9897	0	9897	393	0	24	4.89	324	20.81	668	50.20	195	23.92	34	5.44	0	0.00	7.73	30	4800	20420	49260	23472
36	67.81	9794.0	79	51.51	11274	0	11274	495	0	22	4.47	332	21.29	662	49.90	191	23.91	31	4.96	0	0.00	8.27	35	4400	20940	49080	23520
36	75.04	9790.0	80	43.13	12116	0	12116	530	0	26	5.29	332	21.79	658	49.31	182	23.19	39	6.24	0	0.00	8.68	36	5200	21420	48480	22800
36	77.49	9761.2	78	11.34	12675	0	12675	527	0	26	5.29	312	20.81	666	49.80	184	23.39	36	5.76	0	0.00	9.76	36	5200	20460	48960	22992
36	87.02	9773.6	79	0.27	13971	0	13971	587	0	24	4.88	320	20.87	668	50.05	190	23.51	37	5.92	0	0.00	9.59	36	4800	20540	49260	23136
36	68.48	9780.4	80	53.90	11167	0	11167	496	0	24	4.90	326	21.74	660	49.84	188	23.44	29	4.64	0	0.00	9.73	37	4800	21280	48780	22944
36	73.40	9762.0	80	18.19	11812	0	11812	500	0	22	4.49	340	21.78	662	50.10	188	23.27	40	6.40	0	0.00	10.32	38	4400	21340	49080	22800
36	73.26	9774.8	80	31.14	11956	0	11956	498	0	26	5.27	320	21.27	658	49.15	188	23.41	29	4.64	0	0.00	8.95	29	5200	20980	48480	23088
36	72.95	9779.2	80	40.64	11714	0	11714	497	0	22	4.47	326	20.69	670	50.37	195	23.86	38	6.08	0	0.00	6.62	29	4400	20360	49560	23472
36	72.34	9740.4	80	35.48	11970	0	11970	513	0	22	4.47	320	21.82	662	49.90	183	22.84	33	5.28	0	0.00	9.70	33	4400	21460	49080	22464
36	68.50	9778.8	80	23.42	11375	0	11375	510	0	24	4.87	334	21.68	660	49.50	181	23.19	36	5.76	0	0.00	10.76	38	4800	21360	48780	22848
36*	74.46	9751.6	80	33.03	10315	0	10315	424	0	26	5.33	340	21.72	658	49.71	182	23.23	33	5.28	0	0.00	8.84	37	5200	21180	48480	22656
36*	61.09	9805.2	80	33.43	10107	0	10107	454	0	22	4.49	340	21.76	662	50.06	191	23.69	36	5.76	0	0.00	10.19	36	4400	21340	49080	23232
36*	69.05	9718.4	80	28.38	10695	0	10695	429	0	22	4.53	326	21.11	670	51.00	184	23.36	33	5.28	0	0.00	10.22	39	4400	20520	49560	22704
36*	61.17	9778.0	80	54.21	9766	0	9766	385	0	24	4.91	322	21.40	660	49.89	190	23.81	28	4.48	0	0.00	9.22	35	4800	20920	48780	23280
36*	61.09	9805.2	79	33.10	10098	0	10098	399	0	24	4.90	338	21.66	660	49.75	194	23.69	34	5.44	0	0.00	8.11	29	4800	21240	48780	23232
36*	61.48	9802.0	80	40.40	9784	0	9784	422	0	26	5.31	336	21.73	658	49.46	192	23.51	39	6.24	0	0.00	8.89	32	5200	21300	48480	23040
36*	61.23	9798.8	80	2.78	9820	0	9820	410	0	22	4.49	316	21.37	662	50.09	190	24.05	35	5.60	0	0.00	8.41	33	4400	20940	49080	23568
36*	61.40	9805.6	80	23.45	9913	0	9913	423	0	24	4.90	336	21.27	668	50.24	196	23.59	31	4.96	0	0.00	10.41	34	4800	20860	49260	23136
36*	61.20	9761.2	78	20.01	10010	0	10010	428	0	22	4.51	324	21.41	670	50.77	186	23.31	39	6.24	0	0.00	9.41	35	4400	20900	49560	22752
36*	61.26	9799.2	80	23.07	10067	0	10067	421	0	26	5.31	330	21.76	658	49.47	187	23.46	36	5.76	0	0.00	9.73	36	5200	21320	48480	22992

Table D.26: Results of all runs made with EON network case 5, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.31	10599.2	78	5.57	1046	0	1046	0	0	40	7.55	252	14.04	762	56.72	193	21.69	32	7.31	0	0.00	8.38	30	8000	14880	60120	22992
1	60.61	10619.2	80	29.84	1031	0	1031	0	0	44	8.29	252	14.01	758	56.05	196	21.65	34	7.76	0	0.00	10.22	35	8800	14880	59520	22992
1	60.31	10612.8	76	48.02	1019	0	1019	1	0	38	7.16	246	13.47	772	57.38	195	21.98	31	7.08	0	0.00	10.35	44	7600	14300	60900	23328
1	60.59	10578.8	78	58.13	1022	0	1022	0	0	36	6.81	246	13.52	774	57.85	194	21.82	29	6.62	0	0.00	8.03	26	7200	14300	61200	23088
1	60.29	10612.4	80	34.43	1028	0	1028	0	0	46	8.67	248	13.68	756	55.80	198	21.85	25	5.71	0	0.00	10.62	43	9200	14520	59220	23184
1	60.57	10632.4	80	41.34	1056	0	1056	0	0	42	7.90	252	13.58	768	56.71	195	21.81	29	6.62	0	0.00	8.30	29	8400	14440	60300	23184
1	60.33	10577.2	78	30.98	1030	0	1030	0	0	38	7.19	252	13.50	772	57.58	193	21.74	32	7.31	0	0.00	8.76	45	7600	14280	60900	22992
1	60.56	10624.0	78	6.08	1046	0	1046	0	0	48	9.04	252	13.59	762	55.91	200	21.46	34	7.76	0	0.00	7.86	38	9600	14440	59400	22800
1	60.31	10584.4	79	50.28	1021	0	1021	0	0	40	7.56	246	13.06	770	57.25	199	22.13	27	6.16	0	0.00	9.89	42	8000	13820	60600	23424
1	60.54	10602.8	79	13.74	1031	0	1031	0	0	44	8.30	246	13.34	766	56.59	200	21.78	27	6.16	0	0.00	10.24	32	8800	14140	60000	23088
12	60.59	10554.8	80	18.10	11061	0	11061	2	0	44	8.31	246	13.35	766	56.64	192	21.34	32	7.31	0	0.00	9.46	36	8800	14140	60000	22608
12	60.36	10542.8	79	37.60	10463	0	10463	1	0	52	9.77	248	14.14	746	54.54	189	20.55	34	7.76	0	0.00	10.41	31	10400	15060	58080	21888
12	60.62	10551.2	78	41.15	10655	0	10655	2	0	42	7.91	254	13.23	768	56.76	195	21.41	27	6.16	0	0.00	9.08	38	8400	14060	60300	22752
12	60.39	10558.4	79	55.63	11123	0	11123	1	0	40	7.56	252	13.50	770	57.29	193	21.46	33	7.53	0	0.00	8.05	47	8000	14280	60600	22704
12	60.62	10554.0	79	46.97	10709	0	10709	2	0	38	7.14	248	13.38	772	57.21	194	21.42	33	7.53	0	0.00	9.43	34	7600	14240	60900	22800
12	60.36	10580.4	80	1.47	11139	0	11139	0	0	36	6.78	246	13.17	774	57.67	196	22.07	25	5.71	0	0.00	9.19	35	7200	13980	61200	23424
12	60.67	10569.6	79	15.49	10466	0	10466	2	0	44	8.29	248	13.41	766	56.52	191	21.34	30	6.85	0	0.00	9.08	38	8800	14240	60000	22656
12	60.36	10552.4	80	44.54	11008	0	11008	0	0	36	6.82	250	13.44	774	57.99	191	21.74	27	6.16	0	0.00	8.92	33	7200	14180	61200	22944
12	60.62	10568.0	79	1.81	9903	0	9903	3	0	40	7.55	252	13.48	770	57.20	194	21.52	31	7.08	0	0.00	8.84	39	8000	14280	60600	22800
12	60.68	10563.2	78	41.56	11041	0	11041	0	0	40	7.53	252	13.44	770	57.04	189	21.42	36	8.22	0	0.00	9.65	35	8000	14280	60600	22752
36	66.19	10599.2	80	6.51	12333	0	12333	4	0	44	8.25	244	13.31	766	56.24	196	21.55	25	5.71	0	0.00	11.22	38	8800	14200	60000	22992
36	75.57	10526.4	78	4.03	14011	0	14011	2	0	40	7.53	244	13.37	770	57.05	189	21.15	32	7.31	0	0.00	8.78	36	8000	14200	60600	22464
36	69.50	10547.2	78	46.61	12878	0	12878	0	0	46	8.70	254	13.75	764	56.46	189	20.84	36	8.22	0	0.00	9.03	40	9200	14540	59700	22032
36	77.27	10605.6	79	49.62	14395	0	14395	3	0	46	8.65	250	13.18	764	56.12	199	21.75	29	6.62	0	0.00	8.81	32	9200	14020	59700	23136
36	67.77	10532.8	78	18.47	12608	0	12608	2	0	38	7.13	246	13.12	772	57.15	193	21.44	26	5.94	0	0.00	8.30	50	7600	13980	60900	22848
36	75.13	10524.0	77	46.82	13833	0	13833	1	0	40	7.50	248	13.20	770	56.81	190	21.15	28	6.39	0	0.00	10.32	36	8000	14080	60600	22560
36	75.83	10493.2	78	8.21	13665	0	13665	2	0	44	8.27	254	13.92	758	55.92	185	20.48	26	5.94	0	0.00	10.30	34	8800	14820	59520	21792
36	68.80	10565.6	78	44.20	12692	0	12692	1	0	44	8.28	240	13.58	758	55.97	192	21.53	28	6.39	0	0.00	10.89	52	8800	14440	59520	22896
36	76.10	10556.0	79	45.19	14144	0	14144	5	0	38	7.15	250	13.20	772	57.33	195	21.69	28	6.39	0	0.00	7.89	31	7600	14020	60900	23040
36	77.13	10549.2	79	10.87	14219	0	14219	4	0	40	7.51	246	13.27	770	56.85	192	21.35	37	8.45	0	0.00	7.65	28	8000	14140	60600	22752
36*	61.16	10545.6	78	18.23	11277	0	11277	1	0	40	7.59	244	13.47	770	57.46	191	21.48	32	7.31	0	0.00	10.62	33	8000	14200	60600	22656
36*	71.17	10540.0	79	36.01	12474	0	12474	0	0	54	10.25	250	13.76	756	55.50	189	20.49	31	7.08	0	0.00	9.76	36	10800	14500	58500	21600
36*	60.94	10582.4	79	55.36	11223	0	11223	3	0	38	7.18	246	13.36	772	57.55	195	21.91	27	6.16	0	0.00	8.76	43	7600	14140	60900	23184
36*	61.48	10570.0	80	50.24	10639	0	10639	2	0	38	7.19	244	12.72	780	58.07	199	22.02	34	7.76	0	0.00	10.27	36	7600	13440	61380	23280
36*	61.13	10576.0	80	6.43	10865	0	10865	2	0	44	8.32	248	13.62	766	56.73	193	21.33	40	9.13	0	0.00	8.57	33	8800	14400	60000	22560
36*	61.23	10574.4	80	7.33	11108	0	11108	1	0	44	8.32	248	13.47	766	56.74	193	21.47	30	6.85	0	0.00	9.57	37	8800	14240	60000	22704
36*	68.73	10568.0	79	5.30	12239	0	12239	4	0	40	7.57	252	13.51	770	57.34	194	21.57	31	7.08	0	0.00	8.84	39	8000	14280	60600	22800
36*	61.43	10571.2	77	21.04	10693	0	10693	1	0	48	9.08	244	13.43	762	56.19	194	21.30	32	7.31	0	0.00	9.41	36	9600	14200	59400	22512
36*	61.30	10546.0	80	58.75	11299	0	11299	1	0	40	7.59	246	13.56	770	57.46	190	21.39	32	7.31	0	0.00	9.27	33	8000	14300	60600	22560
36*	66.44	10565.6	79	22.71	11598	0	11598	1	0	42	7.95	246	13.53	768	57.07	191	21.44	28	6.39	0	0.00	10.08	34	8400	14300	60300	22656

Table D.27: Results of all runs made with EON network case 6, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
#T	t_E	C	CA	t_{sol}	#i	#IS	#G_U	#LS_U	UD	#IM	C_{IM}	#MX	C_{MX}	#TX	C_{TX}	#$3R$	C_{3R}	#$10G$	%$10G$	#$40G$	%$40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.57	11950.0	80	17.46	387	0	387	121	0	20	3.35	772	38.24	450	30.58	268	27.92	52	3.33	0	0.00	5.76	29	4000	45700	36540	33360
1	60.76	11907.2	80	10.87	367	0	367	98	0	18	3.02	774	38.06	452	30.94	263	27.98	56	3.58	0	0.00	6.19	36	3600	45320	36840	33312
1	60.72	11908.0	80	43.09	357	0	357	91	0	24	4.03	770	38.98	434	29.58	253	27.41	61	3.90	0	0.00	7.00	45	4800	46420	35220	32640
1	60.39	11836.0	80	44.23	365	0	365	96	0	18	3.04	774	38.66	444	30.72	250	27.58	58	3.71	0	0.00	8.65	43	3600	45760	36360	32640
1	60.89	11948.4	80	6.21	350	0	350	79	0	18	3.01	758	38.62	442	30.33	256	28.04	60	3.84	0	0.00	5.46	43	3600	46140	36240	33504
1	60.48	11888.8	80	6.61	355	0	355	87	0	26	4.37	780	39.06	434	29.47	259	27.09	65	4.16	0	0.00	7.86	37	5200	46440	35040	32208
1	60.76	11905.2	80	6.86	370	0	370	105	0	22	3.70	760	37.28	460	31.05	260	27.98	63	4.03	0	0.00	6.97	37	4400	44380	36960	33312
1	60.33	11940.0	80	25.27	380	0	380	115	0	18	3.02	770	38.19	452	30.85	259	27.94	61	3.90	0	0.00	7.41	35	3600	45600	36840	33360
1	60.75	11942.8	80	3.67	355	0	355	92	0	22	3.68	772	38.00	448	30.34	264	27.97	66	4.22	0	0.00	5.14	30	4400	45380	36240	33408
1	60.37	11960.4	80	57.74	377	0	377	115	0	24	4.01	784	39.63	428	29.15	255	27.21	70	4.48	0	0.00	8.19	28	4800	47400	34860	32544
12	60.57	11894.4	80	46.74	3916	0	3916	1040	0	18	3.02	764	37.91	456	31.08	263	27.68	46	2.94	0	0.00	8.16	27	3600	45240	37080	33024
12	61.03	11872.0	80	19.66	3803	0	3803	1021	0	18	3.01	770	37.75	456	30.99	257	27.48	62	3.97	0	0.00	6.95	39	3600	45160	37080	32880
12	60.62	11918.0	80	9.36	3827	0	3827	1033	0	24	4.00	750	37.01	458	30.58	265	27.83	55	3.52	0	0.00	4.03	20	4800	44360	36660	33360
12	60.96	11897.6	80	3.78	3941	0	3941	1109	0	16	2.68	770	38.19	450	30.86	259	27.78	58	3.71	0	0.00	7.27	31	3200	45660	36900	33216
12	60.50	11753.2	80	53.01	3873	0	3873	1067	0	24	4.01	758	36.74	458	30.64	258	26.84	54	3.45	0	0.00	5.76	41	4800	43960	36660	32112
12	60.86	11822.4	80	40.65	3743	0	3743	974	0	14	2.34	778	37.92	454	31.16	256	27.37	61	3.90	0	0.00	7.38	31	2800	45420	37320	32784
12	60.57	11827.6	80	43.63	3924	0	3924	1103	0	16	2.67	760	36.70	470	31.78	258	27.51	70	4.48	0	0.00	6.68	37	3200	44000	38100	32976
12	60.89	11872.8	80	29.80	3600	0	3600	998	0	22	3.71	778	38.84	440	30.11	254	27.32	54	3.45	0	0.00	5.30	20	4400	46120	35760	32448
12	60.54	11891.2	80	49.55	3974	0	3974	1119	0	18	3.00	772	37.49	462	31.16	255	27.33	57	3.65	0	0.00	6.95	30	3600	45040	37440	32832
12	60.81	11852.4	80	13.14	3905	0	3905	1027	0	24	4.04	770	38.51	438	29.87	249	27.41	52	3.33	0	0.00	6.68	27	4800	45720	35460	32544
36	75.02	11861.6	80	42.28	4834	0	4834	1280	0	14	2.33	766	37.82	456	31.19	252	27.47	58	3.71	0	0.00	8.14	47	2800	45400	37440	32976
36	71.18	11839.2	80	31.32	4368	0	4368	1175	0	18	2.99	780	37.09	460	31.01	255	27.28	55	3.52	0	0.00	5.54	33	3600	44640	37320	32832
36	67.11	11815.6	80	42.14	4213	0	4213	1116	0	18	3.01	764	37.02	464	31.41	257	27.38	55	3.52	0	0.00	8.27	44	3600	44260	37560	32736
36	72.57	11864.0	80	27.14	4606	0	4606	1252	0	20	3.34	756	38.25	444	30.20	253	27.24	47	3.01	0	0.00	8.46	43	4000	45820	36180	32640
36	66.86	11872.4	80	42.17	4268	0	4268	1105	0	16	2.65	766	36.53	468	31.50	262	27.79	54	3.45	0	0.00	5.59	29	3200	44040	37980	33504
36	75.83	11850.0	80	9.49	4954	0	4954	1365	0	14	2.34	766	37.81	454	31.04	255	27.68	62	3.97	0	0.00	5.70	37	2800	45240	37140	33120
36	71.48	11910.8	80	26.32	4662	0	4662	1286	0	22	3.67	768	37.63	452	30.46	257	27.70	62	3.97	0	0.00	7.68	47	4400	45060	36480	33168
36	74.12	11886.0	80	39.20	4904	0	4904	1322	0	26	4.33	778	38.60	432	29.08	255	26.99	58	3.71	0	0.00	6.43	26	5200	46340	34920	32400
36	74.83	11891.2	80	18.21	4768	0	4768	1270	0	20	3.33	756	36.94	462	31.04	260	27.75	52	3.33	0	0.00	7.41	41	4000	44340	37260	33312
36	71.51	11828.0	80	56.68	4454	0	4454	1162	0	22	3.65	776	38.32	442	29.77	250	26.49	64	4.09	0	0.00	5.68	36	4400	46180	35880	31920
36*	61.35	11856.0	80	59.53	4015	0	4015	1134	0	24	4.05	774	39.42	428	29.40	254	27.13	52	3.33	0	0.00	7.41	29	4800	46740	34860	32160
36*	61.56	11894.4	80	47.57	3927	0	3927	1032	0	18	3.03	764	38.03	456	31.17	263	27.76	46	2.94	0	0.00	8.16	27	3600	45240	37080	33024
36*	61.76	11918.0	80	45.76	3857	0	3857	1059	0	24	4.03	750	37.22	458	30.76	265	27.99	55	3.52	0	0.00	4.03	20	4800	44360	36660	33360
36*	76.74	11753.2	80	52.93	4321	0	4321	1162	0	24	4.08	758	37.40	458	31.19	258	27.32	54	3.45	0	0.00	5.76	41	4800	43960	36660	32112
36*	61.57	11857.2	80	26.61	4035	0	4035	1112	0	24	4.05	774	38.95	440	30.01	249	27.08	63	4.03	0	0.00	7.32	31	4800	46180	35580	32112
36*	61.20	11912.8	80	1.73	3943	0	3943	1065	0	18	3.02	750	37.61	456	31.13	259	28.25	63	4.03	0	0.00	7.78	35	3600	44800	37080	33648
36*	61.78	11861.6	80	41.48	3841	0	3841	1030	0	14	2.36	766	38.27	456	31.56	252	27.80	58	3.71	0	0.00	8.14	47	2800	45400	37440	32976
36*	61.31	11815.2	80	34.10	4034	0	4034	1117	0	20	3.39	780	39.12	442	30.52	251	26.98	59	3.77	0	0.00	6.78	30	4000	46220	36060	31872
36*	61.60	11841.2	80	26.51	3868	0	3868	1045	0	16	2.70	758	37.90	460	31.67	252	27.73	60	3.84	0	0.00	7.76	26	3200	44880	37500	32832
36*	67.20	11833.6	80	57.08	4189	0	4189	1149	0	26	4.39	752	37.62	452	30.52	253	27.46	63	4.03	0	0.00	5.92	24	5200	44520	36120	32496

Table D.28: Results of all runs made with EON network case 7, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.67	12162.4	77	35.96	549	0	305	0	0	36	5.92	394	18.53	866	51.75	267	23.80	38	4.86	0	0.00	9.03	39	7200	22540	62940	28944
1	60.40	12180.0	79	45.63	557	0	321	0	0	36	5.91	394	18.77	866	51.67	267	23.65	37	4.73	0	0.00	8.97	49	7200	22860	62940	28800
1	60.68	12160.0	75	55.47	544	0	308	0	0	36	5.92	374	18.63	866	51.76	261	23.68	34	4.35	0	0.00	9.22	40	7200	22660	62940	28800
1	60.37	12231.6	75	48.45	550	0	327	0	0	32	5.23	392	18.61	870	51.95	268	24.21	35	4.48	0	0.00	9.16	36	6400	22760	63540	29616
1	60.70	12156.0	79	35.60	539	0	301	0	0	42	6.91	404	18.95	860	51.04	267	23.10	47	6.01	0	0.00	10.16	44	8400	23040	62040	28080
1	60.36	12225.6	78	46.49	551	0	332	0	0	36	5.89	390	18.40	866	51.48	274	24.22	35	4.48	0	0.00	9.70	42	7200	22500	62940	29616
1	60.67	12203.6	79	8.27	540	0	328	0	0	42	6.88	402	18.80	860	50.84	270	23.48	39	4.99	0	0.00	8.97	40	8400	22940	62040	28656
1	60.36	12182.4	78	59.69	556	0	331	0	0	38	6.24	388	18.78	864	51.42	266	23.56	43	5.50	0	0.00	11.46	51	7600	22880	62640	28704
1	60.68	12128.8	79	26.24	546	0	310	0	0	42	6.93	380	18.53	860	51.15	267	23.39	35	4.48	0	0.00	9.92	45	8400	22480	62040	28368
1	60.37	12221.6	80	3.12	542	0	339	0	0	30	4.91	402	18.82	868	52.04	271	24.23	39	4.99	0	0.00	9.81	42	6000	23000	63600	29616
12	60.48	12132.0	78	20.16	5847	0	3414	2	0	32	5.24	398	18.49	870	52.02	264	23.58	42	5.37	0	0.00	8.76	42	6400	22580	63540	28800
12	60.78	12138.8	79	51.53	5865	0	3315	0	0	32	5.26	392	18.59	870	52.27	260	23.73	46	5.88	0	0.00	9.76	48	6400	22600	63540	28848
12	60.51	12158.8	79	8.94	5714	0	3387	0	0	40	6.58	396	18.62	862	51.27	265	23.53	41	5.24	0	0.00	8.86	52	8000	22640	62340	28608
12	60.86	12123.2	79	19.45	5922	0	3460	0	0	36	5.88	390	18.64	866	51.40	260	23.09	41	5.24	0	0.00	9.22	49	7200	22820	62940	28272
12	60.45	12147.2	78	21.08	5466	0	3240	0	0	38	6.21	388	18.57	864	51.21	261	23.31	42	5.37	0	0.00	10.30	38	7600	22720	62640	28512
12	60.89	12094.4	78	43.37	5772	0	3383	0	0	36	5.91	390	18.74	866	51.70	254	22.99	39	4.99	0	0.00	8.59	41	7200	22820	62940	27984
12	60.47	12167.6	80	29.33	5920	0	3477	0	0	38	6.25	394	18.52	864	51.48	271	23.75	36	4.60	0	0.00	12.62	50	7600	22540	62640	28896
12	60.81	12167.6	79	27.99	5808	0	3434	0	0	38	6.23	386	18.66	864	51.32	264	23.48	43	5.50	0	0.00	10.73	46	7600	22780	62640	28656
12	60.48	12135.2	80	50.28	5875	0	3403	0	0	40	6.56	390	18.44	862	51.08	270	23.36	48	6.14	0	0.00	9.08	39	8000	22500	62340	28512
12	61.03	12123.6	78	52.54	5625	0	3263	0	0	32	5.27	388	18.44	870	52.31	259	23.79	35	4.48	0	0.00	10.24	45	6400	22400	63540	28896
36	77.36	12127.2	76	2.06	7533	0	4406	0	0	40	6.53	390	18.49	862	50.87	263	23.07	39	4.99	0	0.00	10.41	44	8000	22660	62340	28272
36	74.63	12154.4	76	19.10	7287	0	4157	0	0	38	6.21	392	18.47	864	51.20	269	23.46	40	5.12	0	0.00	10.05	58	7600	22600	62640	28704
36	73.60	12170.8	80	51.11	7211	0	4226	0	0	36	5.87	388	18.53	866	51.34	266	23.53	39	4.99	0	0.00	9.16	49	7200	22720	62940	28848
36	73.63	12174.4	79	6.43	7054	0	4076	0	0	38	6.21	388	18.43	864	51.17	264	23.64	40	5.12	0	0.00	9.24	42	7600	22560	62640	28944
36	77.95	12147.6	80	37.02	7663	0	4460	0	0	38	6.26	398	19.08	858	51.27	266	23.39	39	4.99	0	0.00	11.27	50	7600	23180	62280	28416
36	67.22	12151.2	80	25.44	6573	0	3815	0	0	38	6.19	384	18.33	864	50.99	268	23.40	39	4.99	0	0.00	9.73	50	7600	22520	62640	28752
36	68.80	12149.2	78	11.20	6776	0	3991	0	0	34	5.56	386	18.35	868	51.68	266	23.69	35	4.48	0	0.00	9.05	53	6800	22460	63240	28992
36	66.99	12144.8	79	9.14	6648	0	3836	0	0	44	7.25	386	18.76	858	50.84	257	23.16	36	4.60	0	0.00	11.00	50	8800	22780	61740	28128
36	72.48	12132.0	77	15.73	7091	0	4137	0	0	34	5.55	372	18.16	868	51.62	262	23.71	34	4.35	0	0.00	10.65	54	6800	22240	63240	29040
36	74.76	12122.0	77	45.91	7239	0	4219	0	0	34	5.58	394	18.75	868	51.86	259	23.22	43	5.50	0	0.00	11.32	52	6800	22860	63240	28320
36*	61.76	12167.6	78	53.42	6072	0	3518	0	0	38	6.25	386	18.72	864	51.48	264	23.55	43	5.50	0	0.00	9.14	52	7600	22780	62640	28656
36*	61.11	12149.2	80	26.49	5933	0	3472	0	0	40	6.58	380	18.64	862	51.31	264	23.47	41	5.24	0	0.00	10.97	39	8000	22640	62340	28512
36*	61.51	12138.8	79	50.23	6027	0	3499	0	0	32	5.27	392	18.62	870	52.34	260	23.77	46	5.88	0	0.00	9.76	48	6400	22600	63540	28848
36*	61.25	12166.4	78	14.77	5845	0	3424	0	0	40	6.58	386	18.59	862	51.24	263	23.59	42	5.37	0	0.00	9.22	49	8000	22620	62340	28704
36*	61.76	12158.4	80	42.21	5790	0	3363	1	0	38	6.25	396	18.62	864	51.52	266	23.61	32	4.09	0	0.00	8.84	41	7600	22640	62640	28704
36*	61.03	12158.0	79	2.18	5866	0	3448	1	0	44	7.24	380	18.49	858	50.78	263	23.49	31	3.96	0	0.00	10.89	56	8800	22480	61740	28560
36*	61.59	12151.2	76	14.09	5915	0	3495	0	0	30	4.94	392	18.96	866	52.24	266	23.86	39	4.99	0	0.00	9.65	43	6000	23040	63480	28992
36*	75.89	12127.2	76	11.70	7432	0	4415	0	0	40	6.60	390	18.69	862	51.41	263	23.31	39	4.99	0	0.00	10.41	44	8000	22660	62340	28272
36*	61.35	12186.4	78	34.29	5984	0	3463	0	0	38	6.24	392	18.81	864	51.40	263	23.55	45	5.75	0	0.00	10.19	41	7600	22920	62640	28704
36*	66.50	12145.2	79	8.67	5867	0	3456	0	0	32	5.27	384	18.54	870	52.32	263	23.87	34	4.35	0	0.00	10.05	44	6400	22520	63540	28992

Table D.29: Results of all runs made with EON network case 8, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
#T	t_E	C	CA	t_{sol}	#i	#IS	#G_U	#LS_U	UD	#IM	C_{IM}	#MX	C_{MX}	#TX	C_{TX}	#$3R$	C_{3R}	#$10G$	%$10G$	#$40G$	%$40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.42	14620.8	80	34.22	329	0	329	4	0	46	6.29	310	12.34	968	52.28	362	29.09	45	8.21	0	0.00	10.57	47	9200	18040	76440	42528
1	60.45	14614.4	80	40.17	328	0	328	4	0	48	6.57	322	12.99	954	51.61	358	28.84	42	7.66	0	0.00	7.68	26	9600	18980	75420	42144
1	60.78	14634.8	80	52.84	323	0	323	6	0	48	6.56	302	11.86	974	52.35	357	29.22	45	8.21	0	0.00	8.27	35	9600	17360	76620	42768
1	60.50	14706.0	80	7.60	326	0	326	6	0	46	6.26	328	13.37	952	51.33	361	29.05	50	9.12	0	0.00	8.78	39	9200	19660	75480	42720
1	60.79	14593.6	80	6.24	325	0	325	5	0	44	6.03	304	12.38	970	52.58	351	29.01	56	10.22	0	0.00	6.86	31	8800	18060	76740	42336
1	60.42	14632.8	80	38.77	327	0	327	5	0	46	6.29	306	12.41	968	52.24	350	29.06	43	7.85	0	0.00	8.59	41	9200	18160	76440	42528
1	60.73	14622.8	80	30.70	327	0	327	8	0	52	7.11	314	12.47	962	51.66	360	28.76	52	9.49	0	0.00	8.54	35	10400	18240	75540	42048
1	60.48	14630.0	80	7.66	328	0	328	4	0	46	6.29	316	12.43	968	52.25	366	29.04	49	8.94	0	0.00	9.97	32	9200	18180	76440	42480
1	60.78	14611.6	80	47.21	332	0	332	7	0	46	6.30	320	12.58	968	52.31	353	28.81	49	8.94	0	0.00	8.00	35	9200	18380	76440	42096
1	60.47	14650.0	80	53.70	328	0	328	5	0	48	6.55	318	12.48	966	51.97	360	29.00	47	8.58	0	0.00	8.38	35	9600	18280	76140	42480
12	60.64	14567.2	80	8.38	3434	0	3434	71	0	44	6.01	312	12.08	978	52.71	353	28.64	45	8.21	0	0.00	8.78	42	8800	17700	77220	41952
12	61.01	14516.8	80	35.41	3553	0	3553	69	0	50	6.89	314	12.56	964	52.24	347	28.30	54	9.85	0	0.00	9.65	39	10000	18240	75840	41088
12	60.65	14583.6	80	24.91	3543	0	3543	82	0	56	7.66	314	12.37	958	51.26	351	28.47	50	9.12	0	0.00	8.78	45	11200	18080	74940	41616
12	61.00	14466.4	80	18.85	3526	0	3526	70	0	48	6.56	318	12.53	964	51.93	343	27.80	53	9.67	0	0.00	7.65	29	9600	18340	76020	40704
12	60.61	14530.8	80	30.09	3529	0	3529	60	0	44	5.99	310	12.39	970	52.24	346	28.30	47	8.58	0	0.00	7.38	29	8800	18200	76740	41568
12	60.89	14571.6	80	5.65	3465	0	3465	78	0	54	7.35	308	12.95	952	50.91	352	28.01	48	8.76	0	0.00	6.92	36	10800	19020	74760	41136
12	60.67	14549.6	80	38.16	3525	0	3525	62	0	52	7.06	312	11.69	970	51.60	361	28.41	48	8.76	0	0.00	8.95	42	10400	17220	76020	41856
12	60.98	14526.8	80	10.39	3420	0	3420	61	0	48	6.60	318	12.35	966	52.37	346	28.59	48	8.76	0	0.00	7.78	28	9600	17960	76140	41568
12	60.59	14532.4	80	9.72	3520	0	3520	67	0	44	6.00	314	12.85	962	52.01	343	28.25	47	8.58	0	0.00	8.43	33	8800	18840	76260	41424
12	60.93	14553.2	80	4.77	3526	0	3526	60	0	52	7.07	310	12.15	962	51.34	361	28.35	48	8.76	0	0.00	8.78	28	10400	17880	75540	41712
36	76.11	14535.6	80	16.43	4528	0	4528	91	0	46	6.24	328	12.92	960	51.49	346	27.89	50	9.12	0	0.00	7.24	38	9200	19060	75960	41136
36	74.80	14529.2	80	29.08	4355	0	4355	89	0	52	7.05	318	12.27	962	51.17	356	27.93	51	9.31	0	0.00	7.32	30	10400	18120	75540	41232
36	69.84	14541.6	80	3.43	4087	0	4087	66	0	46	6.28	326	11.90	976	52.47	355	28.55	47	8.58	0	0.00	9.00	43	9200	17440	76920	41856
36	75.04	14592.0	80	1.69	4392	0	4392	80	0	48	6.52	308	12.19	966	51.75	347	28.71	53	9.67	0	0.00	8.84	44	9600	17940	76140	42240
36	74.71	14559.2	80	24.24	4347	0	4347	89	0	48	6.54	312	12.35	966	51.84	352	28.40	60	10.95	0	0.00	8.51	34	9600	18140	76140	41712
36	68.16	14560.4	80	38.42	4029	0	4029	71	0	48	6.55	298	11.92	974	52.26	357	28.58	48	8.76	0	0.00	8.00	31	9600	17480	76620	41904
36	72.91	14553.2	80	39.36	4315	0	4315	79	0	48	6.59	320	13.07	954	51.75	351	28.46	46	8.39	0	0.00	8.30	24	9600	19040	75420	41472
36	75.38	14536.0	80	54.80	4457	0	4457	74	0	48	6.53	316	12.48	966	51.79	352	28.08	51	9.31	0	0.00	7.81	30	9600	18340	76140	41280
36	67.58	14542.4	80	17.25	3999	0	3999	55	0	50	6.79	314	12.16	964	51.48	356	28.28	48	8.76	0	0.00	9.03	39	10000	17920	75840	41664
36	70.17	14576.4	80	43.68	4191	0	4191	90	0	48	6.54	318	12.35	966	51.88	354	28.55	48	8.76	0	0.00	8.00	40	9600	18120	76140	41904
36*	61.53	14538.4	80	60.03	3578	0	3578	81	0	46	6.33	308	12.60	964	52.41	344	28.66	45	8.21	0	0.00	8.59	34	9200	18320	76200	41664
36*	61.29	14567.2	80	59.45	3589	0	3589	67	0	44	6.04	312	12.15	978	53.01	353	28.80	45	8.21	0	0.00	8.78	42	8800	17700	77220	41952
36*	61.15	14533.2	80	46.10	3546	0	3546	60	0	38	5.23	308	12.15	984	53.75	347	28.87	56	10.22	0	0.00	7.81	40	7600	17660	78120	41952
36*	61.57	14571.6	80	5.15	3635	0	3635	77	0	54	7.41	308	13.05	952	51.31	352	28.23	48	8.76	0	0.00	6.92	36	10800	19020	74760	41136
36*	66.30	14526.8	80	41.31	3727	0	3727	68	0	48	6.61	318	12.36	966	52.41	346	28.61	48	8.76	0	0.00	7.78	28	9600	17960	76140	41568
36*	61.53	14553.2	80	21.75	3313	0	3313	51	0	52	7.15	310	12.29	962	51.91	361	28.66	48	8.76	0	0.00	8.78	28	10400	17880	75540	41712
36*	73.34	14535.6	80	16.38	3840	0	3840	74	0	46	6.33	328	13.11	960	52.26	346	28.30	50	9.12	0	0.00	7.24	38	9200	19060	75960	41136
36*	61.67	14603.6	80	48.52	3611	0	3611	75	0	48	6.57	322	12.96	958	51.81	355	28.66	45	8.21	0	0.00	7.68	30	9600	18920	75660	41856
36*	61.45	14541.6	80	3.43	3610	0	3610	63	0	46	6.33	326	11.99	976	52.90	355	28.78	47	8.58	0	0.00	9.00	43	9200	17440	76920	41856
36*	61.57	14579.6	80	4.28	3563	0	3563	59	0	56	7.68	294	12.37	958	51.40	345	28.54	48	8.76	0	0.00	8.32	54	11200	18040	74940	41616

Table D.30: Results of all runs made with EON network case 9, in 60 seconds.

D.4 EON, Given 300 Seconds

Symbol	Name
$\#T$	Number of Threads
t_E	Time of Execution
C	Best Cost Solution found
CA	Highest Channel Assigned
t_{sol}	Found Solution Time
$\#i$	Number of Iterations
$\#IS$	Number of Invalid Solutions
$\#G_U$	Number of Greedy Solutions Unfeasible
$\#LS_U$	Number of Local Search Solutions Unfeasible
UD	Unfeasible Degree
$\#IM$	Number of Invert Multiplex used
C_{IM}	Cost % of Invert Multiplex
$\#MX$	Number of Muxponders placed
C_{MX}	Cost % of Muxponders
$\#TX$	Number of Transponders placed
C_{TX}	Cost % of Transponders
$\#3R$	Number of $3R$ regenerators placed
C_{3R}	Cost % of $3R$ regenerators
#10	Number of Multi-Hop Grooming of $10Gb/s$
%10	Traffic % of Multi-Hop Grooming of $10Gb/s$
#40	Number of Multi-hop Grooming of $40Gb/s$
%40	Traffic % of Multi-hop Grooming of $40Gb/s$
$\bar{m}F$	Average Fragmentation at Channel Assigned
MF	Max Fragmentation at Channel Assigned
C_{IM}	Cost of Invert Multiplexers
C_{MX}	Cost of Multiplexers
C_{TX}	Cost of Transponders
C_{3R}	Cost of $3R$ regenerators

Table D.31: Header symbols and their description.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
#T	t_E	C	CA	t_{sol}	#i	#IS	#G_U	#LS_U	UD	#IM	C_{IM}	#MX	C_{MX}	#TX	C_{TX}	#$3R$	C_{3R}	#10G	%10G	#40G	%40G	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.20	6965.2	62	73.24	12154	0	0	0	0	18	5.17	520	37.79	302	34.03	146	23.02	18	1.80	0	0.00	5.46	29	3600	26320	23700	16032
1	300.39	6964.0	64	160.23	12094	0	0	0	0	18	5.17	514	38.05	302	34.03	138	22.75	17	1.70	0	0.00	5.84	31	3600	26500	23700	15840
1	300.22	6976.4	60	64.12	12099	0	0	0	0	18	5.16	504	37.96	302	33.97	138	22.91	23	2.30	0	0.00	4.92	30	3600	26480	23700	15984
1	300.39	6970.0	59	20.56	12235	0	0	0	0	18	5.17	512	38.11	302	34.00	138	22.73	20	2.00	0	0.00	5.05	28	3600	26560	23700	15840
1	300.39	6967.6	58	13.92	12199	0	0	0	0	18	5.17	500	37.95	302	34.01	139	22.87	19	1.90	0	0.00	4.51	31	3600	26440	23700	15936
1	300.24	6961.6	55	12.01	12162	0	0	0	0	20	5.75	516	39.30	294	33.10	136	21.86	17	1.70	0	0.00	4.22	31	4000	27360	23040	15216
1	300.38	6947.6	58	201.51	12145	0	0	0	0	20	5.76	518	37.97	300	33.68	141	22.59	19	1.90	0	0.00	6.51	31	4000	26380	23400	15696
1	300.22	6969.2	52	249.51	12119	0	0	0	0	20	5.74	514	38.02	300	33.58	142	22.66	18	1.80	0	0.00	4.22	27	4000	26500	23400	15792
1	300.38	6966.8	65	46.63	12167	0	0	0	0	18	5.17	504	38.01	302	34.02	137	22.81	15	1.50	0	0.00	6.24	29	3600	26480	23700	15888
1	300.39	6960.8	60	95.43	12165	0	0	0	0	18	5.17	514	38.30	302	34.05	136	22.48	24	2.40	0	0.00	5.22	30	3600	26660	23700	15648
12	300.42	6936.8	59	235.83	114630	0	0	0	0	20	5.73	504	37.71	300	33.53	139	22.42	18	1.80	0	0.00	6.22	32	4000	26320	23400	15648
12	300.25	6934.8	56	259.29	123183	0	0	0	0	16	4.58	514	37.91	304	34.33	136	22.39	19	1.90	0	0.00	5.14	30	3200	26500	24000	15648
12	300.41	6920.4	64	58.59	124572	0	0	0	0	20	5.75	518	38.12	300	33.61	135	21.92	20	2.00	0	0.00	6.57	30	4000	26540	23400	15264
12	300.25	6926.4	59	96.78	121340	0	0	0	0	20	5.76	516	38.27	300	33.67	135	21.96	19	1.90	0	0.00	5.00	25	4000	26600	23400	15264
12	300.39	6943.6	62	142.54	122887	0	0	0	0	16	4.61	502	38.22	304	34.56	132	22.61	20	2.00	0	0.00	5.70	25	3200	26540	24000	15696
12	300.27	6912.8	59	14.31	122937	0	0	0	0	20	5.74	512	38.11	300	33.58	134	21.76	19	1.90	0	0.00	6.05	31	4000	26560	23400	15168
12	300.25	6948.4	63	10.48	123855	0	0	0	0	16	4.59	518	38.06	304	34.42	137	22.58	26	2.60	0	0.00	5.43	30	3200	26540	24000	15744
12	300.41	6934.0	56	48.22	115265	0	0	0	0	18	5.18	516	38.02	302	34.08	137	22.43	21	2.10	0	0.00	4.59	20	3600	26440	23700	15600
12	300.24	6914.4	61	50.03	120180	0	0	0	0	18	5.19	506	38.33	302	34.17	132	22.01	20	2.00	0	0.00	5.27	33	3600	26580	23700	15264
12	300.42	6927.6	61	58.97	108683	0	0	0	0	22	6.32	512	38.16	298	33.19	136	21.86	23	2.30	0	0.00	5.86	24	4400	26560	23100	15216
36	317.63	6934.0	55	10.33	133523	0	0	0	0	18	5.18	500	38.07	302	34.12	134	22.46	16	1.60	0	0.00	4.70	27	3600	26440	23700	15600
36	314.85	6921.6	57	64.35	128612	0	0	0	0	20	5.73	508	37.74	300	33.50	137	22.13	18	1.80	0	0.00	5.19	31	4000	26360	23400	15456
36	305.76	6949.2	57	96.13	129824	0	0	0	0	20	5.73	502	38.04	300	33.54	138	22.29	22	2.20	0	0.00	5.22	29	4000	26540	23400	15552
36	307.38	6939.6	56	273.30	131128	0	0	0	0	18	5.16	520	38.19	302	33.98	137	22.16	20	2.00	0	0.00	5.70	26	3600	26640	23700	15456
36	308.15	6933.6	59	126.80	130903	0	0	0	0	18	5.17	506	38.15	302	34.02	134	22.19	20	2.00	0	0.00	4.78	33	3600	26580	23700	15456
36	316.26	6913.6	55	235.62	133502	0	0	0	0	16	4.57	512	37.47	304	34.27	138	22.42	15	1.50	0	0.00	4.03	22	3200	26240	24000	15696
36	316.45	6945.6	63	3.82	131138	0	0	0	0	16	4.58	504	37.65	304	34.33	139	22.79	18	1.80	0	0.00	5.65	36	3200	26320	24000	15936
36	309.55	6912.8	59	30.89	131761	0	0	0	0	20	5.75	512	38.17	300	33.62	134	21.80	19	1.90	0	0.00	6.05	31	4000	26560	23400	15168
36	315.04	6914.4	61	176.73	133533	0	0	0	0	18	5.16	506	38.08	302	33.96	132	21.87	20	2.00	0	0.00	5.27	33	3600	26580	23700	15264
36	308.80	6934.0	55	46.41	130623	0	0	0	0	18	5.15	500	37.82	302	33.90	134	22.31	16	1.60	0	0.00	4.70	27	3600	26440	23700	15600
36*	300.99	6944.8	62	219.32	127594	0	0	0	0	16	4.61	508	37.96	304	34.56	140	22.88	19	1.90	0	0.00	5.22	31	3200	26360	24000	15888
36*	310.74	6938.4	63	88.91	127323	0	0	0	0	16	4.61	508	38.45	304	34.59	133	22.35	22	2.20	0	0.00	6.16	30	3200	26680	24000	15504
36*	301.14	6939.6	59	86.72	125827	0	0	0	0	16	4.61	506	37.84	304	34.58	139	22.96	18	1.80	0	0.00	4.76	28	3200	26260	24000	15936
36*	310.80	6931.6	59	230.41	127271	0	0	0	0	20	5.77	518	38.52	300	33.76	133	21.95	23	2.30	0	0.00	5.41	31	4000	26700	23400	15216
36*	301.22	6945.2	57	199.15	127952	0	0	0	0	20	5.76	506	38.50	300	33.69	131	22.05	24	2.40	0	0.00	4.57	28	4000	26740	23400	15312
36*	313.86	6924.0	60	33.43	131930	0	0	0	0	18	5.20	506	38.39	302	34.23	130	22.18	22	2.20	0	0.00	4.32	27	3600	26580	23700	15360
36*	301.02	6927.6	61	58.70	128093	0	0	0	0	22	6.35	512	38.34	298	33.34	136	21.96	23	2.30	0	0.00	5.86	24	4400	26560	23100	15216
36*	301.25	6914.4	55	206.34	126143	0	0	0	0	18	5.21	506	38.44	302	34.28	135	22.08	19	1.90	0	0.00	4.92	32	3600	26580	23700	15264
36*	300.89	6934.0	55	9.38	128079	0	0	0	0	18	5.19	500	38.13	302	34.18	134	22.50	16	1.60	0	0.00	4.70	27	3600	26440	23700	15600
36*	301.25	6948.4	62	251.39	126490	0	0	0	0	18	5.18	508	38.40	302	34.11	133	22.31	25	2.50	0	0.00	5.46	30	3600	26680	23700	15504

Table D.32: Results of all runs made with EON network case 1, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.24	8041.2	68	45.52	13700	0	0	0	0	24	5.97	248	18.43	544	49.10	189	26.50	17	3.40	0	0.00	6.16	26	4800	14820	39480	21312
1	300.39	8032.8	55	168.50	13761	0	0	0	0	22	5.48	254	18.35	550	49.82	192	26.35	18	3.60	0	0.00	6.89	23	4400	14740	40020	21168
1	300.42	8023.6	57	92.21	13698	0	0	0	0	24	5.98	242	17.47	556	50.10	194	26.44	18	3.60	0	0.00	6.49	20	4800	14020	40200	21216
1	300.25	8028.0	56	53.62	13700	0	0	0	0	24	5.98	252	18.24	548	49.48	187	26.31	20	4.00	0	0.00	5.92	24	4800	14640	39720	21120
1	300.41	8045.2	62	34.60	13716	0	0	0	0	26	6.46	252	17.45	554	49.59	198	26.49	20	4.00	0	0.00	5.62	23	5200	14040	39900	21312
1	300.24	8021.2	55	255.64	13747	0	0	0	0	24	5.98	254	17.63	556	50.12	194	26.27	31	6.20	0	0.00	7.62	25	4800	14140	40200	21072
1	300.41	8058.0	55	93.87	13701	0	0	0	0	24	5.96	242	17.94	548	49.29	195	26.81	16	3.20	0	0.00	6.59	25	4800	14460	39720	21600
1	300.22	8067.2	64	214.14	13688	0	0	0	0	24	5.95	252	17.21	556	49.83	197	27.01	18	3.60	0	0.00	6.54	29	4800	13880	40200	21792
1	300.22	8058.4	58	81.70	13783	0	0	0	0	22	5.46	242	17.60	558	50.26	194	26.69	21	4.20	0	0.00	6.11	25	4400	14180	40500	21504
1	300.41	8046.8	64	292.42	13624	0	0	0	0	20	4.97	276	19.51	540	49.21	189	26.31	25	5.00	0	0.00	6.14	25	4000	15700	39600	21168
12	300.46	8025.6	54	201.41	119763	0	3	0	0	20	4.96	248	17.37	560	50.62	192	26.62	17	3.40	0	0.00	6.57	22	4000	14000	40800	21456
12	300.27	7993.2	58	276.23	120499	0	1	0	0	22	5.45	244	17.30	558	50.19	191	26.12	18	3.60	0	0.00	5.59	25	4400	13960	40500	21072
12	300.44	8015.6	51	4.01	115049	0	0	0	0	22	5.46	256	18.03	550	49.69	191	26.34	14	2.80	0	0.00	6.38	24	4400	14520	40020	21216
12	300.27	8005.2	52	292.75	120842	0	1	0	0	22	5.50	248	17.29	558	50.59	192	26.62	17	3.40	0	0.00	6.08	23	4400	13840	40500	21312
12	300.25	8007.2	62	164.07	118891	0	2	0	0	22	5.47	254	18.11	550	49.71	188	26.17	17	3.40	0	0.00	5.92	22	4400	14580	40020	21072
12	300.27	8021.6	54	121.99	125181	0	0	0	0	24	5.95	248	17.35	556	49.82	194	26.29	18	3.60	0	0.00	5.81	24	4800	14000	40200	21216
12	300.44	8020.8	58	234.91	121298	0	0	0	0	24	5.98	256	18.10	548	49.52	189	26.39	19	3.80	0	0.00	5.89	24	4800	14520	39720	21168
12	300.27	8000.8	51	37.69	124610	0	0	0	0	24	5.97	248	17.22	556	50.01	195	26.33	18	3.60	0	0.00	5.27	26	4800	13840	40200	21168
12	300.44	8034.4	58	229.43	122247	0	0	0	0	22	5.47	246	18.24	550	49.78	190	26.45	16	3.20	0	0.00	6.27	23	4400	14660	40020	21264
12	300.25	8014.8	55	17.24	117551	0	0	0	0	22	5.47	244	18.10	550	49.74	189	26.31	15	3.00	0	0.00	5.84	23	4400	14560	40020	21168
36	314.14	8013.6	57	64.46	132198	0	0	0	0	26	6.45	246	17.43	554	49.46	190	26.00	19	3.80	0	0.00	6.24	26	5200	14060	39900	20976
36	313.92	8028.4	63	160.37	135656	0	2	0	0	22	5.44	252	17.17	558	50.10	197	26.60	17	3.40	0	0.00	6.59	27	4400	13880	40500	21504
36	305.87	8020.4	55	177.98	132363	0	0	0	0	22	5.47	244	17.15	558	50.34	194	26.73	17	3.40	0	0.00	5.35	20	4400	13800	40500	21504
36	315.56	8023.2	57	207.57	137498	0	1	0	0	24	5.94	240	17.23	556	49.77	192	26.39	20	4.00	0	0.00	6.81	26	4800	13920	40200	21312
36	314.71	8015.6	51	23.00	133683	0	1	0	0	22	5.48	256	18.08	550	49.84	191	26.42	14	2.80	0	0.00	6.38	24	4400	14520	40020	21216
36	311.67	8006.0	53	214.98	132414	0	1	0	0	26	6.48	248	17.24	554	49.70	190	26.31	19	3.80	0	0.00	6.22	28	5200	13840	39900	21120
36	308.80	7993.2	65	188.04	132328	0	2	0	0	22	5.43	248	17.83	550	49.41	188	26.02	17	3.40	0	0.00	5.22	22	4400	14440	40020	21072
36	315.01	8023.6	63	290.72	134959	0	2	0	0	24	5.94	242	17.35	556	49.74	191	26.25	20	4.00	0	0.00	5.97	26	4800	14020	40200	21216
36	312.31	8000.8	51	200.05	128231	0	1	0	0	24	5.94	248	17.13	556	49.77	195	26.21	18	3.60	0	0.00	5.27	26	4800	13840	40200	21168
36	317.94	8020.4	48	38.11	129745	0	2	0	0	24	5.94	254	17.86	548	49.19	190	26.34	18	3.60	0	0.00	6.24	24	4800	14420	39720	21264
36*	312.48	7987.6	65	148.23	140553	0	0	0	0	22	5.51	252	18.13	550	50.10	187	26.26	20	4.00	0	0.00	5.76	26	4400	14480	40020	20976
36*	301.19	8038.8	67	241.60	127411	0	1	0	0	22	5.47	248	17.22	558	50.38	194	26.93	22	4.40	0	0.00	6.24	29	4400	13840	40500	21648
36*	300.74	8036.4	50	197.61	124026	0	1	0	0	22	5.48	244	17.37	558	50.40	194	26.76	19	3.80	0	0.00	7.46	28	4400	13960	40500	21504
36*	301.19	8041.2	57	84.63	130966	0	1	0	0	22	5.47	264	17.96	550	49.77	196	26.80	25	5.00	0	0.00	7.03	23	4400	14440	40020	21552
36*	300.99	7983.6	48	159.26	125989	0	0	0	0	22	5.51	244	17.49	558	50.73	190	26.27	17	3.40	0	0.00	5.78	27	4400	13960	40500	20976
36*	308.40	8026.0	64	236.04	128235	0	1	0	0	26	6.48	252	17.49	554	49.71	193	26.31	19	3.80	0	0.00	6.11	23	5200	14040	39900	21120
36*	300.93	8014.8	54	241.49	131439	0	1	0	0	22	5.49	252	18.47	550	49.93	188	26.11	20	4.00	0	0.00	6.32	24	4400	14800	40020	20928
36*	300.89	8026.8	54	294.09	125406	0	2	0	0	22	5.48	248	17.99	550	49.86	193	26.67	16	3.20	0	0.00	6.19	25	4400	14440	40020	21408
36*	301.19	7980.8	67	261.18	128735	0	1	0	0	22	5.51	246	17.22	558	50.75	192	26.52	17	3.40	0	0.00	5.81	25	4400	13740	40500	21168
36*	301.01	8013.2	71	50.15	127258	0	0	0	0	22	5.49	248	17.67	558	50.54	188	26.30	18	3.60	0	0.00	6.51	27	4400	14160	40500	21072

Table D.33: Results of all runs made with EON network case 2, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.24	8036.0	55	291.86	16677	0	0	0	0	20	4.98	184	12.44	640	63.46	121	19.11	22	6.29	0	0.00	5.43	40	4000	10000	51000	15360
1	300.39	8044.4	52	105.64	16733	0	0	0	0	12	2.98	194	12.85	648	64.89	124	19.27	17	4.86	0	0.00	4.03	30	2400	10340	52200	15504
1	300.22	8017.6	50	138.84	16708	0	0	0	0	12	2.99	180	12.62	648	65.11	122	19.28	21	6.00	0	0.00	3.89	32	2400	10120	52200	15456
1	300.41	8036.0	51	205.09	16663	0	0	0	0	12	2.99	184	12.64	648	64.96	125	19.41	17	4.86	0	0.00	4.51	32	2400	10160	52200	15600
1	300.22	8036.4	51	193.35	16635	0	0	0	0	20	4.98	186	12.57	640	63.46	120	18.99	19	5.43	0	0.00	4.97	34	4000	10100	51000	15264
1	300.41	8038.0	49	234.67	16678	0	0	0	0	16	3.98	192	14.51	624	62.70	111	18.81	21	6.00	0	0.00	4.08	38	3200	11660	50400	15120
1	300.44	7970.8	51	204.25	16675	0	0	0	0	22	5.52	184	12.75	638	63.61	116	18.13	13	3.71	0	0.00	4.78	37	4400	10160	50700	14448
1	300.22	7989.6	50	99.42	16670	0	0	0	0	16	4.01	188	12.37	644	64.58	124	19.04	18	5.14	0	0.00	4.03	35	3200	9880	51600	15216
1	300.41	8029.6	56	112.77	16688	0	0	0	0	12	2.99	184	12.45	648	65.01	126	19.55	16	4.57	0	0.00	3.49	36	2400	10000	52200	15696
1	300.22	8044.8	56	278.80	16653	0	0	0	0	16	3.98	184	12.43	644	64.14	124	19.45	20	5.71	0	0.00	3.78	38	3200	10000	51600	15648
12	300.24	8014.0	51	252.60	169750	0	0	0	0	18	4.48	184	13.18	634	63.20	123	18.80	17	4.86	0	0.00	3.78	26	3600	10600	50820	15120
12	300.44	7999.6	51	225.11	164271	0	0	0	0	16	3.99	186	13.33	636	63.68	120	18.66	20	5.71	0	0.00	3.70	21	3200	10700	51120	14976
12	300.44	8005.2	57	160.73	170137	0	0	0	0	18	4.49	192	12.56	642	63.94	124	18.79	20	5.71	0	0.00	4.19	30	3600	10080	51300	15072
12	300.25	7983.6	50	295.65	168678	0	0	0	0	22	5.47	184	12.42	638	62.97	119	18.30	16	4.57	0	0.00	4.65	36	4400	10000	50700	14736
12	300.38	8005.6	54	169.14	172344	0	0	0	0	22	5.48	182	12.73	638	63.13	119	18.35	17	4.86	0	0.00	4.78	35	4400	10220	50700	14736
12	300.36	7987.2	52	244.53	170070	0	0	0	0	12	2.98	180	12.37	648	64.84	122	19.02	16	4.57	0	0.00	5.00	43	2400	9960	52200	15312
12	301.28	7978.4	52	109.26	163173	0	0	0	0	16	3.98	188	12.70	644	64.25	115	18.41	16	4.57	0	0.00	5.22	36	3200	10200	51600	14784
12	300.46	7985.6	52	277.07	166385	0	0	0	0	12	3.00	188	12.53	648	65.15	121	18.99	19	5.43	0	0.00	6.22	30	2400	10040	52200	15216
12	300.36	8002.0	51	258.30	172132	0	0	0	0	18	4.50	184	12.49	642	64.07	123	18.88	18	5.14	0	0.00	4.92	28	3600	10000	51300	15120
12	300.63	8006.8	50	105.75	170324	0	0	0	0	16	3.97	190	13.13	636	63.43	122	18.82	20	5.71	0	0.00	3.38	16	3200	10580	51120	15168
36	311.10	8006.4	51	9.81	182417	0	0	0	0	16	3.98	184	12.44	644	64.21	120	19.00	21	6.00	0	0.00	4.89	33	3200	10000	51600	15264
36	308.07	8014.8	51	247.20	181487	0	0	0	0	12	2.99	182	12.34	648	65.05	124	19.50	16	4.57	0	0.00	4.81	37	2400	9900	52200	15648
36	309.47	8003.6	50	134.16	183913	0	0	0	0	16	3.97	186	12.73	644	64.03	117	18.58	21	6.00	0	0.00	4.59	42	3200	10260	51600	14976
36	315.90	8008.8	56	216.04	182061	0	0	0	0	16	3.97	180	12.56	644	64.03	116	18.82	17	4.86	0	0.00	4.78	35	3200	10120	51600	15168
36	314.61	7977.2	50	116.11	184693	0	0	0	0	12	2.98	186	12.55	648	64.86	118	18.73	20	5.71	0	0.00	3.95	36	2400	10100	52200	15072
36	308.63	7996.4	49	146.75	180902	0	0	0	0	12	2.98	186	12.56	648	64.89	120	18.97	22	6.29	0	0.00	3.65	37	2400	10100	52200	15264
36	313.70	8012.0	50	137.75	180950	0	0	0	0	18	4.47	186	12.53	642	63.66	123	18.76	20	5.71	0	0.00	4.65	34	3600	10100	51300	15120
36	315.84	8012.0	50	237.04	182076	0	0	0	0	16	3.98	180	12.40	644	64.24	121	19.12	15	4.29	0	0.00	3.59	27	3200	9960	51600	15360
36	308.77	7985.6	54	197.11	184247	0	0	0	0	16	3.97	184	12.21	644	64.05	121	18.89	15	4.29	0	0.00	4.49	18	3200	9840	51600	15216
36	315.73	7989.2	50	3.29	186381	0	0	0	0	20	4.96	182	12.48	640	63.26	117	18.40	21	6.00	0	0.00	3.86	28	4000	10060	51000	14832
36*	301.10	7995.6	51	295.46	168882	0	0	0	0	16	4.00	186	12.43	644	64.54	121	19.03	16	4.57	0	0.00	3.68	24	3200	9940	51600	15216
36*	301.25	8015.6	50	38.63	174098	0	0	0	0	12	2.99	186	12.60	648	65.12	122	19.28	21	6.00	0	0.00	2.92	26	2400	10100	52200	15456
36*	301.00	8008.8	51	292.00	172536	0	0	0	0	16	4.00	172	12.34	644	64.43	120	19.24	14	4.00	0	0.00	4.86	30	3200	9880	51600	15408
36*	301.27	7986.0	50	92.45	175457	0	0	0	0	16	4.01	186	12.45	644	64.61	123	18.93	17	4.86	0	0.00	3.35	21	3200	9940	51600	15120
36*	301.10	8001.6	50	231.75	176380	0	0	0	0	16	4.00	192	12.80	644	64.49	117	18.72	21	6.00	0	0.00	4.16	36	3200	10240	51600	14976
36*	301.08	8021.6	51	282.24	178896	0	0	0	0	16	3.99	180	12.42	644	64.33	119	19.27	20	5.71	0	0.00	4.22	39	3200	9960	51600	15456
36*	301.27	8006.8	49	14.43	176607	0	0	0	0	16	4.00	186	12.61	644	64.45	119	18.94	16	4.57	0	0.00	4.95	24	3200	10100	51600	15168
36*	300.78	8016.4	51	236.07	169343	0	0	0	0	16	3.99	186	12.60	644	64.37	120	19.04	16	4.57	0	0.00	4.32	36	3200	10100	51600	15264
36*	301.10	8012.0	50	133.74	176194	0	0	0	0	16	3.99	180	12.43	644	64.40	121	19.17	15	4.29	0	0.00	3.59	27	3200	9960	51600	15360
36*	301.02	7984.0	52	294.53	174978	0	0	0	0	12	3.01	188	12.98	648	65.38	116	18.64	18	5.14	0	0.00	5.46	41	2400	10360	52200	14880

Table D.34: Results of all runs made with EON network case 3, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.53	8637.6	69	77.22	5930	0	10	0	0	26	6.02	638	38.23	374	33.69	176	22.06	33	2.64	0	0.00	8.62	46	5200	33020	29100	19056
1	300.53	8666.4	64	174.19	5950	0	17	0	0	20	4.62	644	38.45	380	34.62	176	22.32	35	2.80	0	0.00	7.14	29	4000	33320	30000	19344
1	300.25	8663.2	69	240.24	6000	0	17	0	0	20	4.62	644	38.65	380	34.63	171	22.11	36	2.88	0	0.00	7.30	33	4000	33480	30000	19152
1	300.55	8646.8	65	175.17	6029	0	19	0	0	20	4.63	634	38.70	380	34.69	171	21.98	36	2.88	0	0.00	6.16	24	4000	33460	30000	19008
1	300.49	8669.2	64	189.91	5961	0	14	0	0	18	4.15	644	38.25	382	34.95	176	22.65	35	2.80	0	0.00	6.30	29	3600	33160	30300	19632
1	300.52	8654.0	69	274.59	5942	0	17	0	0	24	5.55	634	38.29	376	33.97	176	22.19	34	2.72	0	0.00	7.92	45	4800	33140	29400	19200
1	300.33	8671.2	65	177.92	6013	0	17	0	0	20	4.61	644	38.43	380	34.60	172	22.36	35	2.80	0	0.00	7.22	39	4000	33320	30000	19392
1	300.55	8658.4	63	72.01	5972	0	11	0	0	22	5.08	634	38.28	378	34.30	170	22.34	39	3.12	0	0.00	6.41	28	4400	33140	29700	19344
1	300.32	8616.4	65	0.80	5963	0	15	0	0	22	5.11	632	38.53	378	34.47	171	21.89	35	2.80	0	0.00	6.46	31	4400	33200	29700	18864
1	300.54	8659.2	64	110.74	5997	0	12	0	0	22	5.08	646	38.23	378	34.30	175	22.39	35	2.80	0	0.00	6.51	31	4400	33100	29700	19392
12	300.52	8617.2	65	67.23	60728	0	154	0	0	22	5.10	636	38.14	378	34.41	168	22.19	27	2.16	0	0.00	6.14	31	4400	32920	29700	19152
12	300.59	8627.2	65	5.85	60585	0	147	0	0	20	4.61	640	38.16	380	34.57	168	22.07	31	2.48	0	0.00	7.54	37	4000	33120	30000	19152
12	300.31	8623.2	65	42.82	60729	0	162	0	0	20	4.60	636	38.08	380	34.54	171	22.05	34	2.72	0	0.00	8.49	40	4000	33080	30000	19152
12	300.55	8617.6	65	233.11	60549	0	149	0	0	20	4.63	640	38.32	380	34.71	170	22.05	29	2.32	0	0.00	9.05	42	4000	33120	30000	19056
12	300.33	8646.4	64	130.29	57550	0	157	0	0	22	5.08	638	38.12	378	34.29	176	22.33	32	2.56	0	0.00	6.03	27	4400	33020	29700	19344
12	300.55	8638.4	64	256.00	57581	0	132	0	0	20	4.62	632	38.74	380	34.67	168	21.80	37	2.96	0	0.00	6.73	31	4000	33520	30000	18864
12	300.60	8618.4	63	58.27	59751	0	149	0	0	22	5.08	642	38.38	378	34.32	168	21.80	31	2.48	0	0.00	7.70	42	4400	33220	29700	18864
12	300.33	8635.2	69	46.99	60905	0	144	0	0	26	5.99	642	37.92	374	33.54	177	22.07	36	2.88	0	0.00	7.95	40	5200	32900	29100	19152
12	300.57	8605.2	65	299.16	61546	0	153	0	0	22	5.09	640	38.49	378	34.35	163	21.59	34	2.72	0	0.00	6.30	28	4400	33280	29700	18672
12	300.36	8595.6	64	134.78	61400	0	134	0	0	22	5.07	632	38.10	378	34.25	166	21.70	31	2.48	0	0.00	6.76	29	4400	33040	29700	18816
36	318.10	8624.0	65	216.95	66598	0	148	0	0	20	4.62	640	38.46	380	34.67	169	21.91	35	2.80	0	0.00	7.03	34	4000	33280	30000	18960
36	309.78	8620.4	65	246.09	65712	0	149	0	0	18	4.16	640	38.62	382	34.99	168	21.78	43	3.44	0	0.00	6.70	28	3600	33440	30300	18864
36	314.71	8616.4	65	0.97	67599	0	158	0	0	22	5.09	632	38.43	378	34.38	171	21.84	35	2.80	0	0.00	6.46	31	4400	33200	29700	18864
36	314.96	8629.6	66	54.46	65372	0	170	0	0	24	5.53	640	38.35	376	33.88	166	21.68	30	2.40	0	0.00	8.59	31	4800	33280	29400	18816
36	315.95	8602.0	62	145.60	64767	0	131	0	0	20	4.61	642	38.06	380	34.54	169	21.83	27	2.16	0	0.00	7.54	31	4000	33060	30000	18960
36	307.12	8557.2	62	113.44	65340	0	159	0	0	20	4.67	634	38.73	380	35.06	165	21.54	30	2.40	0	0.00	8.03	34	4000	33140	30000	18432
36	306.07	8645.2	70	145.28	64945	0	169	0	0	20	4.60	650	38.30	380	34.51	174	22.03	27	2.16	0	0.00	8.86	40	4000	33300	30000	19152
36	314.54	8636.4	66	12.36	66801	0	152	0	0	20	4.63	646	38.48	380	34.70	169	22.10	32	2.56	0	0.00	8.38	43	4000	33260	30000	19104
36	306.42	8635.2	69	262.07	65191	0	149	0	0	26	5.99	642	37.91	374	33.53	177	22.07	36	2.88	0	0.00	7.95	40	5200	32900	29100	19152
36	308.10	8639.2	65	99.64	64920	0	142	0	0	20	4.61	636	38.30	380	34.57	171	22.07	29	2.32	0	0.00	7.81	36	4000	33240	30000	19152
36*	310.75	8624.4	64	226.50	63581	0	155	0	0	22	5.10	640	38.59	378	34.44	168	21.87	29	2.32	0	0.00	8.16	40	4400	33280	29700	18864
36*	301.33	8626.8	63	255.37	62042	0	129	0	0	20	4.64	630	38.55	380	34.78	171	22.03	36	2.88	0	0.00	7.89	45	4000	33260	30000	19008
36*	307.74	8616.4	65	3.39	64259	0	140	0	0	22	5.11	632	38.53	378	34.47	171	21.89	35	2.80	0	0.00	6.46	31	4400	33200	29700	18864
36*	301.31	8617.2	65	66.49	62685	0	152	0	0	22	5.11	636	38.20	378	34.47	168	22.23	27	2.16	0	0.00	6.14	31	4400	32920	29700	19152
36*	301.33	8613.2	65	198.81	64241	0	134	0	0	20	4.64	634	38.29	380	34.83	168	22.24	29	2.32	0	0.00	7.08	39	4000	32980	30000	19152
36*	301.13	8652.4	61	288.51	62647	0	140	0	0	20	4.62	630	38.63	380	34.67	169	22.08	45	3.60	0	0.00	7.32	33	4000	33420	30000	19104
36*	301.47	8624.8	65	198.18	63994	0	155	0	0	20	4.64	636	38.54	380	34.78	165	22.04	31	2.48	0	0.00	5.92	28	4000	33240	30000	19008
36*	300.94	8618.4	63	224.98	60631	0	167	0	0	22	5.11	642	38.55	378	34.46	168	21.89	31	2.48	0	0.00	7.70	42	4400	33220	29700	18864
36*	301.41	8634.0	66	171.13	64432	0	180	0	0	22	5.10	640	38.55	378	34.40	169	21.96	32	2.56	0	0.00	8.41	45	4400	33280	29700	18960
36*	300.97	8633.6	65	234.20	62545	0	154	0	0	22	5.10	646	38.71	378	34.40	169	21.79	41	3.28	0	0.00	7.49	38	4400	33420	29700	18816

Table D.35: Results of all runs made with EON network case 4, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.55	9784.4	79	105.38	4609	0	4608	190	0	24	4.91	318	21.05	668	50.35	189	23.69	41	6.56	0	0.00	9.00	32	4800	20600	49260	23184
1	300.32	9780.8	80	219.46	4593	0	4593	185	0	22	4.50	334	21.23	670	50.67	188	23.61	34	5.44	0	0.00	9.65	42	4400	20760	49560	23088
1	300.55	9782.8	80	176.87	4625	0	4625	208	0	24	4.91	330	21.63	660	49.86	188	23.60	36	5.76	0	0.00	7.97	37	4800	21160	48780	23088
1	300.52	9788.8	80	51.96	4624	0	4624	214	0	24	4.90	344	21.68	660	49.83	191	23.59	32	5.12	0	0.00	9.51	34	4800	21220	48780	23088
1	300.32	9797.2	80	230.83	4633	0	4633	193	0	26	5.31	312	21.50	658	49.48	191	23.71	33	5.28	0	0.00	9.68	36	5200	21060	48480	23232
1	300.52	9780.0	79	199.65	4624	0	4624	203	0	24	4.91	320	21.17	668	50.37	189	23.56	40	6.40	0	0.00	7.81	31	4800	20700	49260	23040
1	300.27	9793.2	80	96.16	4606	0	4606	190	0	22	4.49	328	21.67	662	50.12	188	23.72	32	5.12	0	0.00	9.24	33	4400	21220	49080	23232
1	300.57	9798.0	80	255.11	3242	0	3242	129	0	24	4.90	338	21.07	668	50.28	193	23.76	32	5.12	0	0.00	10.27	34	4800	20640	49260	23280
1	300.32	9812.8	79	238.71	4579	0	4579	175	0	26	5.30	334	21.77	658	49.40	188	23.53	29	4.64	0	0.00	9.24	41	5200	21360	48480	23088
1	300.32	9796.8	80	155.64	4597	0	4597	205	0	26	5.31	330	21.15	666	49.98	191	23.57	33	5.28	0	0.00	9.81	40	5200	20720	48960	23088
12	300.38	9747.6	80	221.93	46533	0	46533	2002	0	22	4.50	320	20.84	670	50.69	190	23.66	28	4.48	0	0.00	10.65	36	4400	20380	49560	23136
12	300.63	9772.4	80	212.22	46135	0	46135	1979	0	26	5.32	328	21.10	666	50.10	191	23.48	39	6.24	0	0.00	8.62	37	5200	20620	48960	22944
12	300.39	9719.6	79	64.94	46812	0	46812	1987	0	22	4.50	328	21.52	662	50.15	188	23.15	36	5.76	0	0.00	9.24	32	4400	21060	49080	22656
12	300.63	9752.4	80	191.85	48828	0	48828	2118	0	28	5.73	326	21.79	656	49.34	186	23.01	36	5.76	0	0.00	8.84	29	5600	21280	48180	22464
12	300.36	9744.0	80	124.27	44942	0	44942	1819	0	22	4.48	338	21.79	662	49.97	187	22.97	37	5.92	0	0.00	9.22	43	4400	21400	49080	22560
12	300.36	9746.0	79	207.59	46816	0	46814	1904	0	22	4.50	340	21.65	662	50.16	185	23.30	32	5.12	0	0.00	9.16	30	4400	21180	49080	22800
12	300.60	9768.4	80	293.30	47628	0	47628	2016	0	24	4.91	326	21.15	668	50.39	188	23.47	35	5.60	0	0.00	8.81	33	4800	20680	49260	22944
12	300.35	9755.2	79	189.18	46843	0	46843	1962	0	26	5.32	314	20.86	666	50.08	187	23.52	36	5.76	0	0.00	9.65	32	5200	20400	48960	22992
12	300.63	9770.8	80	70.47	48260	0	48259	2160	0	26	5.30	328	20.85	666	49.89	191	23.52	36	5.76	0	0.00	9.05	32	5200	20460	48960	23088
12	300.38	9776.8	80	165.55	48355	0	48354	2080	0	20	4.09	344	21.53	664	50.48	189	23.85	32	5.12	0	0.00	7.86	28	4000	21060	49380	23328
36	311.10	9708.4	78	269.46	51675	0	51675	2218	0	22	4.49	328	21.81	662	50.07	182	22.67	40	6.40	0	0.00	11.03	36	4400	21380	49080	22224
36	315.54	9743.6	80	17.94	51657	0	51657	2171	0	22	4.48	328	21.43	662	49.93	186	23.29	35	5.60	0	0.00	10.03	42	4400	21060	49080	22896
36	308.22	9771.6	78	18.36	51030	0	51030	2175	0	24	4.89	334	21.65	668	50.21	184	22.85	39	6.24	0	0.00	9.16	36	4800	21240	49260	22416
36	309.82	9762.8	79	113.77	51453	0	51453	2188	0	20	4.07	326	21.02	672	50.68	185	23.47	38	6.08	0	0.00	10.35	34	4000	20680	49860	23088
36	306.52	9735.6	80	21.78	50985	0	50985	2126	0	22	4.48	328	21.62	662	50.01	185	23.08	34	5.44	0	0.00	10.32	37	4400	21220	49080	22656
36	317.29	9676.4	80	190.91	52042	0	52041	2169	0	24	4.92	330	21.23	668	50.48	184	22.53	34	5.44	0	0.00	10.16	36	4800	20720	49260	21984
36	313.98	9757.2	80	162.52	52462	0	52462	2258	0	26	5.32	336	21.62	658	49.57	186	23.27	29	4.64	0	0.00	9.38	34	5200	21140	48480	22752
36	315.63	9708.8	79	91.10	51605	0	51605	2158	0	22	4.50	338	21.70	662	50.14	185	22.85	34	5.44	0	0.00	9.97	41	4400	21240	49080	22368
36	314.62	9768.4	80	269.49	50046	0	50045	2110	0	24	4.88	326	21.02	668	50.06	188	23.32	35	5.60	0	0.00	8.81	33	4800	20680	49260	22944
36	309.89	9749.6	80	142.49	50967	0	50967	2150	0	22	4.48	330	20.79	670	50.50	193	23.58	33	5.28	0	0.00	7.95	29	4400	20400	49560	23136
36*	301.03	9742.4	80	279.68	48254	0	48254	1995	0	30	6.16	318	21.14	662	49.64	183	23.06	36	5.76	0	0.00	9.27	40	6000	20600	48360	22464
36*	301.50	9732.4	79	149.71	49874	0	49874	2118	0	22	4.52	336	21.72	662	50.43	184	23.33	31	4.96	0	0.00	10.14	39	4400	21140	49080	22704
36*	301.36	9755.6	80	93.55	49756	0	49756	2083	0	22	4.51	332	21.96	662	50.31	188	23.22	36	5.76	0	0.00	11.00	44	4400	21420	49080	22656
36*	301.31	9737.6	79	37.91	48748	0	48748	1961	0	20	4.11	324	21.92	664	50.71	182	23.27	36	5.76	0	0.00	8.35	31	4000	21340	49380	22656
36*	317.04	9775.2	80	137.06	47916	0	47916	1938	0	24	4.91	348	21.91	660	49.90	186	23.28	40	6.40	0	0.00	10.95	41	4800	21420	48780	22752
36*	301.13	9735.6	80	17.39	49546	0	49546	2066	0	22	4.52	328	21.80	662	50.41	185	23.27	34	5.44	0	0.00	10.32	37	4400	21220	49080	22656
36*	301.35	9756.8	80	283.25	49080	0	49079	2064	0	24	4.92	340	21.42	668	50.49	189	23.17	34	5.44	0	0.00	10.92	37	4800	20900	49260	22608
36*	300.91	9718.4	80	83.04	49488	0	49488	2101	0	22	4.53	326	21.11	670	51.00	184	23.36	33	5.28	0	0.00	10.22	39	4400	20520	49560	22704
36*	301.35	9708.8	79	93.10	49246	0	49246	2074	0	22	4.53	338	21.88	662	50.55	185	23.04	34	5.44	0	0.00	9.97	41	4400	21240	49080	22368
36*	301.13	9761.6	79	237.74	50200	0	50200	2149	0	26	5.33	330	21.06	666	50.16	189	23.46	32	5.12	0	0.00	8.95	36	5200	20560	48960	22896

Table D.36: Results of all runs made with EON network case 5, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.55	10585.6	79	125.25	5211	0	5211	2	0	52	9.82	248	13.45	758	55.55	196	21.18	27	6.16	0	0.00	10.76	40	10400	14240	58800	22416
1	300.32	10582.4	79	168.56	5156	0	5156	1	0	46	8.69	254	13.44	764	56.41	196	21.45	27	6.16	0	0.00	9.68	41	9200	14220	59700	22704
1	300.60	10600.4	78	175.19	5165	0	5165	1	0	42	7.92	244	13.55	768	56.88	194	21.64	34	7.76	0	0.00	10.16	35	8400	14360	60300	22944
1	300.55	10581.2	79	172.72	5180	0	5180	0	0	50	9.45	244	13.42	760	55.85	197	21.28	27	6.16	0	0.00	8.89	35	10000	14200	59100	22512
1	300.32	10562.8	79	174.17	5161	0	5161	0	0	44	8.33	254	13.46	766	56.80	195	21.40	30	6.85	0	0.00	8.19	36	8800	14220	60000	22608
1	300.57	10553.6	80	234.03	5152	0	5152	1	0	40	7.58	244	13.30	770	57.42	195	21.70	28	6.39	0	0.00	8.57	29	8000	14040	60600	22896
1	300.33	10576.0	80	191.82	5143	0	5143	0	0	48	9.08	244	13.43	762	56.16	196	21.33	36	8.22	0	0.00	10.46	38	9600	14200	59400	22560
1	300.55	10582.0	76	263.22	5182	0	5182	0	0	42	7.94	256	13.53	768	56.98	194	21.55	28	6.39	0	0.00	9.43	31	8400	14320	60300	22800
1	300.57	10570.4	79	152.46	5169	0	5169	0	0	50	9.46	254	13.60	760	55.91	194	21.02	30	6.85	0	0.00	10.59	40	10000	14380	59100	22224
1	300.33	10571.2	77	19.06	5191	0	5191	1	0	48	9.08	244	13.43	762	56.19	194	21.30	32	7.31	0	0.00	9.41	36	9600	14200	59400	22512
12	300.38	10545.2	79	31.00	55483	0	55483	7	0	40	7.56	242	13.32	770	57.24	192	21.49	31	7.08	0	0.00	8.32	39	8000	14100	60600	22752
12	300.64	10544.4	78	39.23	53083	0	53083	9	0	44	8.33	250	13.42	766	56.80	195	21.27	30	6.85	0	0.00	9.16	32	8800	14180	60000	22464
12	300.36	10538.8	80	204.20	53943	0	53943	8	0	44	8.34	246	13.26	766	56.89	195	21.44	29	6.62	0	0.00	9.95	38	8800	13980	60000	22608
12	300.61	10539.6	80	248.85	52401	0	52401	9	0	44	8.33	242	13.19	766	56.78	194	21.44	26	5.94	0	0.00	8.95	46	8800	13940	60000	22656
12	300.66	10531.6	80	109.47	53747	0	53747	3	0	40	7.56	246	13.51	770	57.25	190	21.18	30	6.85	0	0.00	8.43	42	8000	14300	60600	22416
12	300.36	10532.0	78	27.71	52967	0	52967	5	0	42	7.94	246	13.52	768	57.01	192	21.10	35	7.99	0	0.00	8.86	32	8400	14300	60300	22320
12	300.63	10486.8	78	277.51	54835	0	54835	9	0	46	8.72	248	13.34	764	56.56	189	20.74	32	7.31	0	0.00	10.00	43	9200	14080	59700	21888
12	300.38	10554.4	80	281.08	53135	0	53135	5	0	44	8.34	244	13.30	766	56.85	193	21.51	26	5.94	0	0.00	8.22	28	8800	14040	60000	22704
12	300.64	10568.0	79	1.72	54395	0	54395	7	0	40	7.55	252	13.48	770	57.19	194	21.52	31	7.08	0	0.00	8.84	39	8000	14280	60600	22800
12	300.36	10546.4	80	94.46	54539	0	54539	5	0	40	7.54	240	13.35	770	57.15	190	21.41	34	7.76	0	0.00	10.59	33	8000	14160	60600	22704
36	306.60	10523.2	78	97.52	57578	0	57578	7	0	50	9.50	242	13.40	760	56.16	195	20.94	34	7.76	0	0.00	9.59	41	10000	14100	59100	22032
36	311.63	10555.6	78	101.49	57045	0	57045	11	0	44	8.27	242	13.25	766	56.40	194	21.30	27	6.16	0	0.00	8.16	37	8800	14100	60000	22656
36	309.29	10524.4	78	178.98	57021	0	57021	8	0	38	7.15	244	13.21	772	57.28	193	21.35	28	6.39	0	0.00	10.03	41	7600	14040	60900	22704
36	312.28	10528.0	77	252.72	58842	0	58842	7	0	40	7.53	248	13.96	762	56.57	186	21.00	27	6.16	0	0.00	9.00	31	8000	14840	60120	22320
36	307.46	10493.2	78	18.03	55484	0	55484	7	0	44	8.35	254	14.05	758	56.45	185	20.67	26	5.94	0	0.00	10.30	34	8800	14820	59520	21792
36	306.87	10550.8	78	291.47	56740	0	56740	8	0	50	9.41	252	13.44	760	55.62	190	20.82	37	8.45	0	0.00	9.14	36	10000	14280	59100	22128
36	308.90	10548.0	78	76.36	58394	0	58394	7	0	44	8.29	252	13.31	766	56.54	196	21.26	32	7.31	0	0.00	9.57	34	8800	14120	60000	22560
36	314.57	10546.4	79	40.03	59128	0	59128	9	0	40	7.55	248	13.60	770	57.21	189	21.21	29	6.62	0	0.00	10.11	41	8000	14400	60600	22464
36	311.73	10554.0	79	174.33	58846	0	58846	9	0	38	7.15	248	13.39	772	57.26	194	21.44	33	7.53	0	0.00	9.43	34	7600	14240	60900	22800
36	314.76	10524.0	77	100.21	58562	0	58562	4	0	40	7.54	248	13.27	770	57.09	190	21.25	28	6.39	0	0.00	10.32	36	8000	14080	60600	22560
36*	301.47	10549.2	79	8.42	56299	0	56299	7	0	40	7.58	246	13.40	770	57.45	192	21.57	37	8.45	0	0.00	7.65	28	8000	14140	60600	22752
36*	301.00	10547.2	78	75.32	52338	0	52338	6	0	46	8.72	254	13.79	764	56.60	189	20.89	36	8.22	0	0.00	9.03	40	9200	14540	59700	22032
36*	301.00	10557.6	79	256.46	54898	0	54898	14	0	48	9.09	248	13.64	762	56.26	189	21.00	32	7.31	0	0.00	9.59	37	9600	14400	59400	22176
36*	301.42	10524.4	78	121.24	56560	0	56560	5	0	38	7.22	244	13.34	772	57.87	193	21.57	28	6.39	0	0.00	10.03	41	7600	14040	60900	22704
36*	317.23	10528.0	77	251.44	57749	0	57749	6	0	40	7.60	248	14.10	762	57.10	186	21.20	27	6.16	0	0.00	9.00	31	8000	14840	60120	22320
36*	301.28	10493.2	78	8.13	53083	0	53083	14	0	44	8.39	254	14.12	758	56.72	185	20.77	26	5.94	0	0.00	10.30	34	8800	14820	59520	21792
36*	301.31	10538.8	80	201.10	54895	0	54895	9	0	44	8.35	246	13.27	766	56.93	195	21.45	29	6.62	0	0.00	9.95	38	8800	13980	60000	22608
36*	301.24	10551.2	78	58.42	55953	0	55953	6	0	42	7.96	254	13.33	768	57.15	195	21.56	27	6.16	0	0.00	9.08	38	8400	14060	60300	22752
36*	301.19	10520.4	78	264.53	51945	0	51945	5	0	44	8.36	250	13.48	766	57.03	191	21.12	35	7.99	0	0.00	8.59	33	8800	14180	60000	22224
36*	307.38	10542.8	79	204.31	52620	0	52620	4	0	52	9.86	248	14.28	746	55.09	189	20.76	34	7.76	0	0.00	10.41	31	10400	15060	58080	21888

Table D.37: Results of all runs made with EON network case 6, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.66	11866.8	80	226.23	1795	0	1795	469	0	18	3.03	778	37.67	462	31.55	259	27.75	56	3.58	0	0.00	6.95	36	3600	44700	37440	32928
1	300.72	11899.6	80	219.70	1821	0	1821	488	0	18	3.03	768	39.11	436	30.15	252	27.71	51	3.26	0	0.00	5.41	27	3600	46540	35880	32976
1	300.38	11902.8	80	82.12	1812	0	1812	478	0	18	3.02	782	37.96	452	30.95	261	28.07	65	4.16	0	0.00	5.35	28	3600	45180	36840	33408
1	300.74	11899.2	80	246.82	1800	0	1800	478	0	20	3.36	780	38.34	450	30.71	264	27.59	58	3.71	0	0.00	6.84	39	4000	45620	36540	32832
1	300.39	11858.4	80	293.98	1809	0	1809	476	0	12	2.02	768	37.49	470	32.43	255	28.05	77	4.93	0	0.00	7.92	38	2400	44460	38460	33264
1	300.35	11887.6	80	280.64	1816	0	1816	488	0	20	3.36	776	38.75	448	30.64	250	27.34	63	4.03	0	0.00	7.84	38	4000	46060	36420	32496
1	300.66	11799.6	80	156.00	1820	0	1820	488	0	14	2.37	762	37.75	464	32.14	251	27.74	60	3.84	0	0.00	5.05	31	2800	44540	37920	32736
1	300.69	11914.0	80	103.62	1805	0	1805	465	0	18	3.02	772	38.46	444	30.52	259	28.00	56	3.58	0	0.00	6.73	33	3600	45820	36360	33360
1	300.38	11909.6	80	143.32	1817	0	1817	499	0	14	2.35	772	39.01	448	31.03	249	27.69	59	3.77	0	0.00	6.22	35	2800	46460	36960	32976
1	300.86	11909.6	80	194.69	1823	0	1823	486	0	24	4.03	770	38.10	446	30.18	258	27.69	58	3.71	0	0.00	6.05	29	4800	45380	35940	32976
12	300.80	11872.8	80	280.43	19026	0	19026	5230	0	18	3.02	774	37.65	456	31.11	257	27.83	51	3.26	0	0.00	7.16	32	3600	44880	37080	33168
12	300.69	11769.2	80	108.93	19484	0	19484	5279	0	20	3.35	752	36.51	466	31.40	254	27.29	57	3.65	0	0.00	6.81	33	4000	43600	37500	32592
12	300.61	11846.0	80	95.61	19064	0	19064	5274	0	16	2.69	756	37.20	470	32.01	257	27.63	72	4.61	0	0.00	6.11	36	3200	44280	38100	32880
12	301.14	11816.4	80	113.49	19010	0	19010	5183	0	18	3.03	764	37.66	456	31.24	253	27.62	54	3.45	0	0.00	6.84	30	3600	44700	37080	32784
12	300.74	11836.8	80	72.56	19144	0	19144	5139	0	22	3.70	770	37.93	454	30.74	253	27.05	66	4.22	0	0.00	7.08	43	4400	45160	36600	32208
12	300.60	11843.2	80	31.48	19333	0	19333	5276	0	20	3.36	762	38.13	448	30.58	257	27.36	53	3.39	0	0.00	7.97	31	4000	45420	36420	32592
12	300.80	11844.0	80	144.80	18505	0	18505	5093	0	22	3.69	766	37.11	460	31.03	257	27.61	57	3.65	0	0.00	6.54	42	4400	44200	36960	32880
12	300.75	11846.0	80	250.85	18480	0	18480	5005	0	20	3.37	770	38.14	450	30.78	259	27.49	62	3.97	0	0.00	6.41	34	4000	45280	36540	32640
12	300.88	11843.6	80	45.85	19104	0	19104	5173	0	20	3.36	766	37.11	462	31.28	255	27.69	66	4.22	0	0.00	5.43	29	4000	44200	37260	32976
12	300.89	11845.6	80	173.88	19450	0	19450	5290	0	28	4.70	776	38.86	436	29.33	246	26.44	52	3.33	0	0.00	7.16	37	5600	46340	34980	31536
36	316.32	11839.2	80	106.77	20825	0	20825	5730	0	18	3.01	780	37.26	460	31.15	255	27.41	55	3.52	0	0.00	5.54	33	3600	44640	37320	32832
36	317.45	11862.0	80	238.10	20463	0	20463	5498	0	22	3.69	780	37.68	446	30.26	258	27.75	57	3.65	0	0.00	6.54	25	4400	44980	36120	33120
36	313.74	11753.2	80	52.52	20508	0	20508	5559	0	24	4.03	758	36.88	458	30.76	258	26.94	54	3.45	0	0.00	5.76	41	4800	43960	36660	32112
36	312.94	11830.0	80	139.66	20590	0	20590	5513	0	16	2.67	766	37.04	466	31.61	254	27.45	58	3.71	0	0.00	6.78	30	3200	44360	37860	32880
36	313.20	11769.2	80	106.70	20780	0	20780	5586	0	20	3.34	752	36.40	466	31.31	254	27.21	57	3.65	0	0.00	6.81	33	4000	43600	37500	32592
36	309.11	11842.0	80	263.73	20266	0	20266	5434	0	18	3.01	780	37.92	460	31.21	257	26.90	66	4.22	0	0.00	6.84	33	3600	45340	37320	32160
36	315.03	11833.6	80	36.00	20680	0	20680	5723	0	24	4.03	786	38.50	442	30.00	254	26.90	60	3.84	0	0.00	5.73	30	4800	45820	35700	32016
36	309.58	11871.2	80	178.85	20201	0	20201	5507	0	20	3.34	770	37.90	446	30.34	256	27.65	51	3.26	0	0.00	6.05	40	4000	45340	36300	33072
36	310.81	11822.4	80	249.44	20496	0	20496	5614	0	22	3.67	776	36.55	464	31.02	265	27.34	62	3.97	0	0.00	6.14	33	4400	43840	37200	32784
36	307.66	11870.4	80	69.42	20247	0	20247	5519	0	16	2.68	778	37.55	462	31.49	257	27.64	63	4.03	0	0.00	8.08	28	3200	44860	37620	33024
36*	301.31	11782.8	80	146.27	19670	0	19670	5314	0	20	3.39	782	37.83	460	31.52	253	27.33	65	4.16	0	0.00	5.81	35	4000	44580	37140	32208
36*	301.49	11753.2	80	55.71	19176	0	19176	5003	0	24	4.08	758	37.40	458	31.19	258	27.32	54	3.45	0	0.00	5.76	41	4800	43960	36660	32112
36*	301.22	11835.2	80	201.63	19625	0	19625	5348	0	24	4.06	752	38.55	440	30.06	250	27.34	58	3.71	0	0.00	7.62	42	4800	45620	35580	32352
36*	301.39	11769.6	80	259.05	19198	0	19198	5219	0	22	3.74	764	37.66	456	31.20	255	27.41	57	3.65	0	0.00	6.68	25	4400	44320	36720	32256
36*	311.27	11849.2	80	227.50	20044	0	20044	5463	0	20	3.38	772	38.57	450	30.84	253	27.30	62	3.97	0	0.00	6.11	42	4000	45700	36540	32352
36*	301.20	11808.4	80	271.19	19200	0	19200	5279	0	22	3.73	768	37.70	456	31.10	258	27.56	62	3.97	0	0.00	7.43	39	4400	44520	36720	32544
36*	301.50	11828.0	80	37.91	18725	0	18725	5173	0	22	3.72	776	39.04	442	30.33	250	26.99	64	4.09	0	0.00	5.68	36	4400	46180	35880	31920
36*	301.49	11833.6	80	45.94	19900	0	19900	5465	0	24	4.06	786	38.72	442	30.17	254	27.06	60	3.84	0	0.00	5.73	30	4800	45820	35700	32016
36*	301.31	11809.6	80	255.81	19463	0	19463	5395	0	18	3.05	752	38.34	454	31.30	249	27.31	55	3.52	0	0.00	7.68	29	3600	45280	36960	32256
36*	315.37	11832.4	80	270.32	20034	0	20034	5437	0	18	3.04	758	38.12	456	31.34	252	27.50	61	3.90	0	0.00	7.32	28	3600	45100	37080	32544

Table D.38: Results of all runs made with EON network case 7, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.66	12160.8	77	35.21	2691	0	1563	0	0	32	5.26	398	18.57	870	52.25	267	23.92	37	4.73	0	0.00	9.35	40	6400	22580	63540	29088
1	300.46	12147.6	78	82.82	2716	0	1555	0	0	36	5.93	384	18.67	866	51.81	264	23.59	41	5.24	0	0.00	9.89	42	7200	22680	62940	28656
1	300.69	12175.2	75	41.22	2713	0	1579	0	0	38	6.24	384	18.50	864	51.45	269	23.81	38	4.86	0	0.00	10.70	43	7600	22520	62640	28992
1	300.41	12160.4	74	235.89	2686	0	1580	0	0	32	5.26	380	18.49	870	52.25	265	24.00	39	4.99	0	0.00	10.38	45	6400	22480	63540	29184
1	300.69	12174.8	80	58.05	2713	0	1570	1	0	42	6.90	386	18.45	860	50.96	272	23.69	41	5.24	0	0.00	9.03	49	8400	22460	62040	28848
1	300.66	12130.4	79	104.79	2711	0	1560	0	0	34	5.61	396	18.80	868	52.13	265	23.47	46	5.88	0	0.00	9.38	43	6800	22800	63240	28464
1	300.35	12180.4	74	194.50	2708	0	1569	0	0	38	6.24	386	18.57	864	51.43	264	23.76	37	4.73	0	0.00	10.46	44	7600	22620	62640	28944
1	300.69	12179.6	79	214.42	2734	0	1583	0	0	38	6.24	398	18.80	864	51.43	267	23.53	45	5.75	0	0.00	10.95	57	7600	22900	62640	28656
1	300.44	12159.6	79	122.80	2735	0	1615	0	0	42	6.91	382	18.70	860	51.02	266	23.37	41	5.24	0	0.00	10.16	38	8400	22740	62040	28416
1	300.75	12117.2	80	158.33	2732	0	1613	0	0	42	6.93	394	18.73	860	51.20	262	23.13	39	4.99	0	0.00	9.84	49	8400	22700	62040	28032
12	300.78	12134.0	77	156.34	28804	0	16838	0	0	40	6.57	376	18.83	862	51.20	252	23.06	43	5.50	0	0.00	11.19	47	8000	22920	62340	28080
12	300.49	12097.2	77	194.94	25579	0	14792	0	0	36	5.92	388	18.95	866	51.78	255	22.86	44	5.63	0	0.00	7.76	44	7200	23040	62940	27792
12	300.46	12123.2	79	20.84	28569	0	16718	0	0	36	5.90	390	18.70	866	51.58	260	23.17	41	5.24	0	0.00	9.22	49	7200	22820	62940	28272
12	300.78	12124.4	80	126.69	29806	0	17350	1	0	34	5.59	390	18.49	868	51.96	263	23.58	41	5.24	0	0.00	8.32	38	6800	22500	63240	28704
12	300.50	12160.8	78	82.46	26429	0	15493	0	0	40	6.57	390	18.61	862	51.20	265	23.50	38	4.86	0	0.00	9.92	46	8000	22660	62340	28608
12	300.77	12100.4	77	41.53	28804	0	16840	0	0	30	4.96	394	18.76	872	52.76	259	23.52	41	5.24	0	0.00	10.86	44	6000	22700	63840	28464
12	300.49	12133.6	79	255.98	28269	0	16530	0	0	36	5.93	394	18.55	866	51.81	264	23.59	32	4.09	0	0.00	9.41	48	7200	22540	62940	28656
12	300.55	12095.6	77	156.55	28963	0	16976	0	0	40	6.61	376	18.55	862	51.54	256	23.29	32	4.09	0	0.00	9.00	41	8000	22440	62340	28176
12	300.80	12121.6	77	165.41	29533	0	17055	0	0	40	6.57	394	18.64	862	51.18	262	23.13	42	5.37	0	0.00	11.22	46	8000	22700	62340	28176
12	300.49	12126.0	80	116.92	29179	0	16913	1	0	36	5.92	388	18.55	866	51.74	263	23.48	37	4.73	0	0.00	9.16	39	7200	22560	62940	28560
36	310.56	12136.4	77	44.16	30973	0	17930	1	0	34	5.58	386	18.58	868	51.94	263	23.57	44	5.63	0	0.00	9.68	39	6800	22620	63240	28704
36	315.54	12095.2	78	213.13	31279	0	18166	0	0	40	6.57	382	18.55	862	51.22	259	23.03	41	5.24	0	0.00	10.97	54	8000	22580	62340	28032
36	307.41	12112.0	80	233.95	30974	0	18064	1	0	40	6.56	386	18.42	862	51.13	262	23.23	37	4.73	0	0.00	9.19	43	8000	22460	62340	28320
36	315.20	12117.2	79	34.34	31316	0	18342	0	0	30	4.92	382	18.50	872	52.32	265	23.56	41	5.24	0	0.00	9.19	46	6000	22580	63840	28752
36	312.84	12123.2	79	108.56	31413	0	18335	0	0	36	5.88	390	18.64	866	51.41	260	23.09	41	5.24	0	0.00	9.22	49	7200	22820	62940	28272
36	312.23	12138.4	78	64.79	31237	0	18275	1	0	36	5.91	378	18.49	866	51.64	266	23.55	36	4.60	0	0.00	9.57	40	7200	22540	62940	28704
36	312.48	12143.2	77	212.66	30654	0	17828	1	0	38	6.22	392	18.35	864	51.23	271	23.52	42	5.37	0	0.00	9.81	42	7600	22440	62640	28752
36	319.16	12122.0	77	275.26	31592	0	18503	0	0	38	6.22	390	18.55	864	51.29	259	23.19	36	4.60	0	0.00	9.16	37	7600	22660	62640	28320
36	306.56	12135.2	80	282.30	28810	0	16819	0	0	44	7.21	386	18.28	858	50.62	270	23.38	35	4.48	0	0.00	10.62	53	8800	22300	61740	28512
36	317.44	12128.8	76	103.02	31885	0	18639	1	0	32	5.25	398	18.66	870	52.14	262	23.47	45	5.75	0	0.00	8.78	36	6400	22740	63540	28608
36*	301.30	12111.6	74	283.41	27827	0	16282	0	0	40	6.61	392	18.66	862	51.47	262	23.26	36	4.60	0	0.00	9.86	39	8000	22600	62340	28176
36*	301.56	12063.6	77	19.24	29766	0	17333	0	0	34	5.64	382	18.98	868	52.42	248	22.96	39	4.99	0	0.00	10.51	37	6800	22900	63240	27696
36*	301.08	12117.2	79	145.67	29610	0	17166	0	0	30	4.95	382	18.63	872	52.69	265	23.73	41	5.24	0	0.00	9.19	46	6000	22580	63840	28752
36*	301.39	12123.2	79	76.38	29546	0	17270	0	0	36	5.94	390	18.82	866	51.92	260	23.32	41	5.24	0	0.00	9.22	49	7200	22820	62940	28272
36*	301.20	12085.6	80	86.21	28806	0	16770	1	0	38	6.29	384	18.77	864	51.83	258	23.12	45	5.75	0	0.00	10.76	55	7600	22680	62640	27936
36*	301.28	12100.4	77	167.08	29998	0	17510	2	0	30	4.96	394	18.76	872	52.76	259	23.52	41	5.24	0	0.00	10.86	44	6000	22700	63840	28464
36*	301.13	12132.0	78	97.67	30229	0	17580	1	0	32	5.28	398	18.61	870	52.37	264	23.74	42	5.37	0	0.00	8.76	42	6400	22580	63540	28800
36*	301.44	12135.2	80	237.29	27287	0	15923	1	0	40	6.59	390	18.54	862	51.37	270	23.50	48	6.14	0	0.00	9.08	39	8000	22500	62340	28512
36*	301.10	12096.8	80	171.37	30027	0	17511	0	0	34	5.62	388	18.65	868	52.28	261	23.45	36	4.60	0	0.00	10.03	40	6800	22560	63240	28368
36*	301.47	12128.8	76	18.13	29928	0	17437	0	0	32	5.28	398	18.75	870	52.39	262	23.59	45	5.75	0	0.00	8.78	36	6400	22740	63540	28608

Table D.39: Results of all runs made with EON network case 8, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.89	14606.8	80	227.45	1643	0	1643	28	0	48	6.57	318	12.51	966	52.13	351	28.79	55	10.04	0	0.00	9.05	34	9600	18280	76140	42048
1	300.72	14583.6	80	13.70	1650	0	1650	36	0	48	6.58	314	12.51	966	52.21	355	28.70	50	9.12	0	0.00	9.30	41	9600	18240	76140	41856
1	300.44	14657.2	80	122.82	1647	0	1647	31	0	46	6.28	304	12.13	976	52.48	356	29.11	55	10.04	0	0.00	7.62	41	9200	17780	76920	42672
1	300.80	14601.2	80	247.70	1635	0	1635	30	0	48	6.57	314	12.38	966	52.15	357	28.90	51	9.31	0	0.00	7.92	44	9600	18080	76140	42192
1	300.74	14560.0	80	135.52	1654	0	1654	36	0	48	6.59	316	12.60	966	52.29	353	28.52	49	8.94	0	0.00	8.89	24	9600	18340	76140	41520
1	300.39	14506.8	80	192.55	1643	0	1643	28	0	52	7.17	306	11.77	970	52.40	355	28.65	47	8.58	0	0.00	9.32	35	10400	17080	76020	41568
1	300.88	14547.2	80	105.50	1657	0	1657	43	0	48	6.60	308	12.55	966	52.34	351	28.51	50	9.12	0	0.00	7.49	32	9600	18260	76140	41472
1	300.36	14576.4	80	272.98	1651	0	1651	37	0	46	6.31	320	12.50	968	52.44	354	28.75	61	11.13	0	0.00	8.86	31	9200	18220	76440	41904
1	300.78	14593.6	80	270.07	1626	0	1626	17	0	46	6.30	330	13.13	960	52.05	348	28.52	53	9.67	0	0.00	7.11	30	9200	19160	75960	41616
1	300.44	14572.8	80	194.17	1626	0	1626	23	0	52	7.14	328	13.57	940	50.93	351	28.36	48	8.76	0	0.00	9.05	48	10400	19780	74220	41328
12	300.92	14546.8	80	57.27	17216	0	17216	348	0	54	7.41	312	12.75	952	51.28	348	28.35	48	8.76	0	0.00	6.59	37	10800	18580	74760	41328
12	300.89	14532.0	80	109.15	17634	0	17634	341	0	42	5.78	318	12.47	972	53.01	348	28.74	57	10.40	0	0.00	9.51	31	8400	18120	77040	41760
12	300.61	14513.6	80	258.71	17314	0	17314	319	0	44	6.03	304	12.49	970	52.63	338	28.37	49	8.94	0	0.00	9.49	41	8800	18220	76740	41376
12	300.72	14553.2	80	129.53	17706	0	17706	357	0	42	5.75	324	12.91	964	52.42	340	28.56	50	9.12	0	0.00	7.38	37	8400	18860	76560	41712
12	302.22	14499.2	80	147.65	17053	0	17053	334	0	44	6.02	320	12.47	970	52.52	350	28.22	47	8.58	0	0.00	9.73	38	8800	18220	76740	41232
12	300.55	14546.8	80	49.58	17362	0	17362	357	0	44	6.02	314	12.89	962	52.16	346	28.43	54	9.85	0	0.00	7.05	34	8800	18840	76260	41568
12	300.57	14503.6	80	180.85	17182	0	17182	348	0	56	7.68	318	13.16	950	51.04	339	27.54	51	9.31	0	0.00	9.14	37	11200	19200	74460	40176
12	300.88	14550.8	80	1.34	17858	0	17858	352	0	48	6.60	306	11.85	974	52.65	354	28.89	44	8.03	0	0.00	7.81	29	9600	17240	76620	42048
12	300.60	14560.0	80	277.24	17617	0	17617	351	0	44	6.04	320	12.40	970	52.71	355	28.85	49	8.94	0	0.00	9.97	43	8800	18060	76740	42000
12	300.89	14542.4	80	8.69	17821	0	17821	327	0	50	6.85	314	12.28	964	51.98	356	28.56	48	8.76	0	0.00	9.03	39	10000	17920	75840	41664
36	313.64	14505.6	80	283.78	18948	0	18948	418	0	46	6.31	318	12.20	968	52.41	354	28.53	47	8.58	0	0.00	8.41	29	9200	17800	76440	41616
36	311.49	14541.6	80	16.80	17412	0	17412	329	0	46	6.26	326	11.87	976	52.37	355	28.49	47	8.58	0	0.00	9.00	43	9200	17440	76920	41856
36	310.67	14518.4	80	243.25	18385	0	18385	357	0	52	7.09	316	12.80	954	51.16	344	27.91	52	9.49	0	0.00	8.97	49	10400	18780	75060	40944
36	313.56	14538.8	80	41.96	18716	0	18716	338	0	52	7.09	310	12.20	962	51.53	355	28.36	47	8.58	0	0.00	7.70	53	10400	17880	75540	41568
36	313.64	14514.4	80	296.82	18656	0	18656	320	0	48	6.53	320	12.39	966	51.77	348	28.00	51	9.31	0	0.00	8.38	32	9600	18220	76140	41184
36	316.10	14436.4	80	72.93	18699	0	18699	358	0	36	4.90	326	12.29	978	53.08	345	28.05	47	8.58	0	0.00	7.51	28	7200	18040	77940	41184
36	308.49	14517.6	80	262.53	18544	0	18544	348	0	44	6.05	308	12.54	970	52.72	347	28.42	52	9.49	0	0.00	8.70	29	8800	18260	76740	41376
36	309.33	14515.2	80	111.49	18598	0	18598	367	0	46	6.28	310	12.32	968	52.21	348	28.33	46	8.39	0	0.00	7.43	30	9200	18040	76440	41472
36	314.11	14449.6	80	26.49	18788	0	18788	339	0	52	7.11	304	12.24	962	51.65	341	27.80	47	8.58	0	0.00	7.70	47	10400	17900	75540	40656
36	311.83	14506.8	80	289.93	18657	0	18657	329	0	52	7.10	306	11.67	970	51.92	355	28.39	47	8.58	0	0.00	9.32	35	10400	17080	76020	41568
36*	308.74	14528.8	80	209.15	17874	0	17874	337	0	44	6.06	308	12.35	970	52.82	350	28.78	54	9.85	0	0.00	7.73	37	8800	17940	76740	41808
36*	301.67	14505.6	80	282.25	17917	0	17917	379	0	46	6.34	318	12.27	968	52.70	354	28.69	47	8.58	0	0.00	8.41	29	9200	17800	76440	41616
36*	301.16	14457.6	80	262.44	18134	0	18134	352	0	48	6.64	304	12.08	974	53.00	345	28.29	47	8.58	0	0.00	6.86	25	9600	17460	76620	40896
36*	301.35	14496.4	80	225.26	16324	0	16324	308	0	44	6.07	314	12.58	970	52.94	345	28.41	50	9.12	0	0.00	9.16	41	8800	18240	76740	41184
36*	301.69	14570.0	80	245.28	17773	0	17773	342	0	54	7.41	312	12.45	960	51.64	344	28.50	51	9.31	0	0.00	6.86	33	10800	18140	75240	41520
36*	301.50	14514.4	80	243.97	17358	0	17358	333	0	48	6.61	320	12.55	966	52.46	348	28.37	51	9.31	0	0.00	8.38	32	9600	18220	76140	41184
36*	301.75	14568.0	80	180.27	17893	0	17893	344	0	44	6.04	312	12.45	970	52.68	352	28.83	39	7.12	0	0.00	7.43	35	8800	18140	76740	42000
36*	301.31	14477.6	80	282.17	18046	0	18046	359	0	46	6.35	322	12.43	968	52.80	346	28.41	47	8.58	0	0.00	9.22	56	9200	18000	76440	41136
36*	301.52	14422.0	80	209.90	16778	0	16778	337	0	44	6.10	318	12.56	970	53.21	340	28.12	50	9.12	0	0.00	7.65	34	8800	18120	76740	40560
36*	301.58	14503.6	80	166.06	17948	0	17948	350	0	56	7.72	318	13.24	950	51.34	339	27.70	51	9.31	0	0.00	9.14	37	11200	19200	74460	40176

Table D.40: Results of all runs made with EON network case 9, in 300 seconds.

D.5 GBN, Given 60 Seconds

Symbol	Name
$\#T$	Number of Threads
t_E	Time of Execution
C	Best Cost Solution found
CA	Highest Channel Assigned
t_{sol}	Found Solution Time
$\#i$	Number of Iterations
$\#IS$	Number of Invalid Solutions
$\#G_U$	Number of Greedy Solutions Unfeasible
$\#LS_U$	Number of Local Search Solutions Unfeasible
UD	Unfeasible Degree
$\#IM$	Number of Invert Multiplex used
C_{IM}	Cost % of Invert Multiplex
$\#MX$	Number of Muxponders placed
C_{MX}	Cost % of Muxponders
$\#TX$	Number of Transponders placed
C_{TX}	Cost % of Transponders
$\#3R$	Number of $3R$ regenerators placed
C_{3R}	Cost % of $3R$ regenerators
#10	Number of Multi-Hop Grooming of $10Gb/s$
%10	Traffic % of Multi-Hop Grooming of $10Gb/s$
#40	Number of Multi-hop Grooming of $40Gb/s$
%40	Traffic % of Multi-hop Grooming of $40Gb/s$
$\bar{m}F$	Average Fragmentation at Channel Assigned
MF	Max Fragmentation at Channel Assigned
C_{IM}	Cost of Invert Multiplexers
C_{MX}	Cost of Multiplexers
C_{TX}	Cost of Transponders
C_{3R}	Cost of $3R$ regenerators

Table D.41: Header symbols and their description.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
#T	t_E	C	CA	t_{sol}	#i	#IS	#G_U	#LS_U	UD	#IM	C_{IM}	#MX	C_{MX}	#TX	C_{TX}	#$3R$	C_{3R}	#$10G$	%$10G$	#$40G$	%$40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.36	4736.0	58	55.80	9395	0	0	0	0	0	0.00	464	49.32	280	50.68	0	0.00	11	1.22	0	0.00	13.65	36	0	23360	24000	0
1	60.20	4736.0	57	4.43	9395	0	0	0	0	0	0.00	464	49.32	280	50.68	0	0.00	13	1.44	0	0.00	12.23	33	0	23360	24000	0
1	60.36	4736.0	55	2.56	9415	0	0	0	0	0	0.00	464	49.32	280	50.68	0	0.00	13	1.44	0	0.00	10.73	25	0	23360	24000	0
1	60.20	4736.0	57	29.53	9399	0	0	0	0	0	0.00	464	49.32	280	50.68	0	0.00	8	0.89	0	0.00	11.23	28	0	23360	24000	0
1	60.36	4736.0	58	27.39	9419	0	0	0	0	0	0.00	464	49.32	280	50.68	0	0.00	15	1.67	0	0.00	13.15	32	0	23360	24000	0
1	60.22	4736.0	57	47.69	9361	0	0	0	0	0	0.00	464	49.32	280	50.68	0	0.00	11	1.22	0	0.00	11.50	24	0	23360	24000	0
1	60.36	4736.0	62	42.65	9427	0	0	0	0	0	0.00	464	49.32	280	50.68	0	0.00	11	1.22	0	0.00	14.58	37	0	23360	24000	0
1	60.20	4736.0	60	17.82	9449	0	0	0	0	0	0.00	464	49.32	280	50.68	0	0.00	11	1.22	0	0.00	13.62	36	0	23360	24000	0
1	60.34	4736.0	58	37.05	9416	0	0	0	0	0	0.00	464	49.32	280	50.68	0	0.00	14	1.56	0	0.00	11.62	28	0	23360	24000	0
1	60.36	4736.0	58	10.00	9410	0	0	0	0	0	0.00	464	49.32	280	50.68	0	0.00	10	1.11	0	0.00	11.88	42	0	23360	24000	0
12	60.37	4730.0	58	59.50	88056	0	0	0	0	0	0.00	466	49.20	280	50.68	0	0.00	8	0.89	0	0.00	13.92	28	0	23300	24000	0
12	60.23	4736.0	56	22.15	89213	0	0	0	0	0	0.00	464	49.32	280	50.68	0	0.00	12	1.33	0	0.00	10.73	24	0	23360	24000	0
12	60.37	4730.0	59	25.55	92804	0	0	0	0	0	0.00	466	49.20	280	50.68	0	0.00	11	1.22	0	0.00	14.08	37	0	23300	24000	0
12	60.22	4736.0	56	57.58	94761	0	0	0	0	0	0.00	464	49.32	280	50.68	0	0.00	9	1.00	0	0.00	11.27	31	0	23360	24000	0
12	60.37	4730.0	59	53.73	94924	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	12	1.33	0	0.00	12.00	33	0	23300	24000	0
12	60.23	4732.0	61	35.90	92022	0	0	0	0	0	0.00	460	49.28	280	50.72	0	0.00	9	1.00	0	0.00	11.65	34	0	23320	24000	0
12	60.39	4730.0	58	12.08	95093	0	0	0	0	0	0.00	466	49.20	280	50.68	0	0.00	9	1.00	0	0.00	14.92	27	0	23300	24000	0
12	60.37	4730.0	58	53.51	91144	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	10	1.11	0	0.00	12.31	40	0	23300	24000	0
12	60.23	4730.0	57	50.70	92893	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	13	1.44	0	0.00	10.77	19	0	23300	24000	0
12	60.37	4730.0	59	14.77	88793	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	11	1.22	0	0.00	11.88	36	0	23300	24000	0
36	68.17	4730.0	59	10.37	105947	0	0	0	0	0	0.00	466	49.20	280	50.68	0	0.00	10	1.11	0	0.00	12.69	30	0	23300	24000	0
36	67.72	4730.0	57	3.29	110460	0	0	0	0	0	0.00	466	49.20	280	50.68	0	0.00	11	1.22	0	0.00	10.85	31	0	23300	24000	0
36	68.13	4730.0	58	9.64	109555	0	0	0	0	0	0.00	466	49.16	280	50.63	0	0.00	8	0.89	0	0.00	10.54	26	0	23300	24000	0
36	77.34	4730.0	58	44.15	123322	0	0	0	0	0	0.00	466	49.20	280	50.68	0	0.00	11	1.22	0	0.00	13.62	35	0	23300	24000	0
36	67.80	4730.0	60	57.36	106387	0	0	0	0	0	0.00	466	49.20	280	50.68	0	0.00	9	1.00	0	0.00	12.62	30	0	23300	24000	0
36	66.63	4730.0	59	46.53	106727	0	0	0	0	0	0.00	466	49.20	280	50.68	0	0.00	11	1.22	0	0.00	11.77	28	0	23300	24000	0
36	66.02	4730.0	61	29.75	105648	0	0	0	0	0	0.00	466	49.20	280	50.68	0	0.00	8	0.89	0	0.00	12.65	28	0	23300	24000	0
36	75.05	4730.0	61	10.20	119895	0	0	0	0	0	0.00	466	49.20	280	50.68	0	0.00	10	1.11	0	0.00	14.96	31	0	23300	24000	0
36	70.31	4730.0	57	21.90	112653	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	10	1.11	0	0.00	12.81	39	0	23300	24000	0
36	76.52	4730.0	60	46.74	121578	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	10	1.11	0	0.00	12.15	26	0	23300	24000	0
36*	68.17	4730.0	59	10.37	105947	0	0	0	0	0	0.00	466	49.20	280	50.68	0	0.00	10	1.11	0	0.00	12.69	30	0	23300	24000	0
36*	67.72	4730.0	57	3.29	110460	0	0	0	0	0	0.00	466	49.20	280	50.68	0	0.00	11	1.22	0	0.00	10.85	31	0	23300	24000	0
36*	68.13	4730.0	58	9.64	109555	0	0	0	0	0	0.00	466	49.16	280	50.63	0	0.00	8	0.89	0	0.00	10.54	26	0	23300	24000	0
36*	77.34	4730.0	58	44.15	123322	0	0	0	0	0	0.00	466	49.20	280	50.68	0	0.00	11	1.22	0	0.00	13.62	35	0	23300	24000	0
36*	67.80	4730.0	60	57.36	106387	0	0	0	0	0	0.00	466	49.20	280	50.68	0	0.00	9	1.00	0	0.00	12.62	30	0	23300	24000	0
36*	66.63	4730.0	59	46.53	106727	0	0	0	0	0	0.00	466	49.20	280	50.68	0	0.00	11	1.22	0	0.00	11.77	28	0	23300	24000	0
36*	66.02	4730.0	61	29.75	105648	0	0	0	0	0	0.00	466	49.20	280	50.68	0	0.00	8	0.89	0	0.00	12.65	28	0	23300	24000	0
36*	75.05	4730.0	61	10.20	119895	0	0	0	0	0	0.00	466	49.20	280	50.68	0	0.00	10	1.11	0	0.00	14.96	31	0	23300	24000	0
36*	70.31	4730.0	57	21.90	112653	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	10	1.11	0	0.00	12.81	39	0	23300	24000	0
36*	76.52	4730.0	60	46.74	121578	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	10	1.11	0	0.00	12.15	26	0	23300	24000	0

Table D.42: Results of all runs made with GBN network case 1, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.22	5178.0	73	17.47	10434	0	371	25	0	0	0.00	212	22.94	530	77.06	0	0.00	9	2.00	0	0.00	14.35	31	0	11880	39900	0
1	60.36	5178.0	73	39.83	10499	0	364	31	0	0	0.00	212	22.94	530	77.06	0	0.00	10	2.22	0	0.00	13.92	34	0	11880	39900	0
1	60.22	5178.0	76	11.43	10458	0	384	29	0	0	0.00	212	22.94	530	77.06	0	0.00	8	1.78	0	0.00	16.00	33	0	11880	39900	0
1	60.34	5178.0	73	40.50	10529	0	343	28	0	0	0.00	212	22.94	530	77.06	0	0.00	9	2.00	0	0.00	16.15	33	0	11880	39900	0
1	60.22	5178.0	74	1.86	10451	0	370	32	0	0	0.00	212	22.94	530	77.06	0	0.00	8	1.78	0	0.00	13.54	27	0	11880	39900	0
1	60.36	5176.0	73	23.17	10472	0	349	22	0	0	0.00	202	22.91	530	77.09	0	0.00	8	1.78	0	0.00	16.35	37	0	11860	39900	0
1	60.22	5178.0	72	54.58	10497	0	397	32	0	0	0.00	212	22.94	530	77.06	0	0.00	8	1.78	0	0.00	16.31	40	0	11880	39900	0
1	60.36	5178.0	74	6.07	10472	0	375	26	0	0	0.00	212	22.94	530	77.06	0	0.00	9	2.00	0	0.00	14.23	30	0	11880	39900	0
1	60.20	5178.0	73	24.74	10478	0	366	20	0	0	0.00	212	22.94	530	77.06	0	0.00	9	2.00	0	0.00	18.27	51	0	11880	39900	0
1	60.36	5178.0	74	40.68	10453	0	389	27	0	0	0.00	212	22.94	530	77.06	0	0.00	9	2.00	0	0.00	15.23	30	0	11880	39900	0
12	60.37	5178.0	72	11.30	94313	0	3315	247	0	0	0.00	212	22.94	530	77.06	0	0.00	8	1.78	0	0.00	17.15	39	0	11880	39900	0
12	60.37	5178.0	72	47.35	93468	0	3292	236	0	0	0.00	212	22.94	530	77.06	0	0.00	8	1.78	0	0.00	18.00	35	0	11880	39900	0
12	60.23	5178.0	72	11.06	84999	0	2968	208	0	0	0.00	212	22.94	530	77.06	0	0.00	7	1.56	0	0.00	16.58	51	0	11880	39900	0
12	60.39	5178.0	72	1.05	92894	0	3105	244	0	0	0.00	212	22.94	530	77.06	0	0.00	10	2.22	0	0.00	15.58	30	0	11880	39900	0
12	60.22	5176.0	77	56.75	90000	0	3052	195	0	0	0.00	202	22.90	530	77.06	0	0.00	8	1.78	0	0.00	13.58	38	0	11860	39900	0
12	60.31	5176.0	73	28.39	87356	0	2994	167	0	0	0.00	202	22.90	530	77.06	0	0.00	8	1.78	0	0.00	15.96	33	0	11860	39900	0
12	60.40	5178.0	72	21.12	93403	0	3314	237	0	0	0.00	212	22.94	530	77.06	0	0.00	7	1.56	0	0.00	16.65	34	0	11880	39900	0
12	60.47	5178.0	72	25.91	88529	0	3128	211	0	0	0.00	212	22.94	530	77.06	0	0.00	7	1.56	0	0.00	17.12	38	0	11880	39900	0
12	60.23	5178.0	72	8.02	86640	0	2999	212	0	0	0.00	212	22.94	530	77.06	0	0.00	10	2.22	0	0.00	19.35	43	0	11880	39900	0
12	60.31	5178.0	72	11.23	83676	0	3002	208	0	0	0.00	212	22.94	530	77.06	0	0.00	10	2.22	0	0.00	15.50	35	0	11880	39900	0
36	72.04	5178.0	72	18.71	105901	0	3615	274	0	0	0.00	212	22.93	530	77.03	0	0.00	9	2.00	0	0.00	16.00	32	0	11880	39900	0
36	68.69	5178.0	72	6.61	107111	0	3714	255	0	0	0.00	212	22.93	530	77.03	0	0.00	7	1.56	0	0.00	14.73	36	0	11880	39900	0
36	72.60	5178.0	72	12.89	107015	0	3679	241	0	0	0.00	212	22.94	530	77.06	0	0.00	8	1.78	0	0.00	15.12	35	0	11880	39900	0
36	73.51	5178.0	72	30.58	116737	0	4093	315	0	0	0.00	212	22.94	530	77.06	0	0.00	8	1.78	0	0.00	16.96	43	0	11880	39900	0
36	69.12	5178.0	72	14.77	104272	0	3673	281	0	0	0.00	212	22.93	530	77.00	0	0.00	7	1.56	0	0.00	15.77	37	0	11880	39900	0
36	72.31	5178.0	73	7.58	109030	0	3722	259	0	0	0.00	212	22.94	530	77.06	0	0.00	10	2.22	0	0.00	14.27	28	0	11880	39900	0
36	66.80	5176.0	75	19.11	102194	0	3574	261	0	0	0.00	202	22.90	530	77.06	0	0.00	8	1.78	0	0.00	17.19	40	0	11860	39900	0
36	67.75	5178.0	72	50.70	108111	0	3729	272	0	0	0.00	212	22.94	530	77.06	0	0.00	9	2.00	0	0.00	14.38	29	0	11880	39900	0
36	70.43	5178.0	72	0.97	104373	0	3696	251	0	0	0.00	212	22.94	530	77.06	0	0.00	10	2.22	0	0.00	15.58	30	0	11880	39900	0
36	67.69	5178.0	72	19.42	106257	0	3677	251	0	0	0.00	212	22.93	530	77.03	0	0.00	8	1.78	0	0.00	14.35	32	0	11880	39900	0
36*	73.21	5178.0	72	3.43	96258	0	3250	214	0	0	0.00	212	22.94	530	77.06	0	0.00	7	1.56	0	0.00	13.00	26	0	11880	39900	0
36*	73.85	5178.0	72	43.10	93287	0	3191	240	0	0	0.00	212	22.94	530	77.06	0	0.00	10	2.22	0	0.00	16.58	34	0	11880	39900	0
36*	73.88	5178.0	72	37.18	117243	0	4006	295	0	0	0.00	212	22.94	530	77.06	0	0.00	7	1.56	0	0.00	13.00	29	0	11880	39900	0
36*	73.09	5178.0	72	50.45	105684	0	3739	283	0	0	0.00	212	22.94	530	77.06	0	0.00	10	2.22	0	0.00	16.31	32	0	11880	39900	0
36*	67.98	5178.0	72	53.04	101602	0	3569	240	0	0	0.00	212	22.94	530	77.06	0	0.00	10	2.22	0	0.00	19.35	43	0	11880	39900	0
36*	73.77	5178.0	73	35.55	109802	0	3732	257	0	0	0.00	212	22.94	530	77.06	0	0.00	8	1.78	0	0.00	17.62	39	0	11880	39900	0
36*	74.04	5178.0	72	9.24	110097	0	3783	259	0	0	0.00	212	22.94	530	77.06	0	0.00	9	2.00	0	0.00	13.31	35	0	11880	39900	0
36*	72.60	5178.0	72	11.64	108712	0	3736	244	0	0	0.00	212	22.94	530	77.06	0	0.00	8	1.78	0	0.00	15.12	35	0	11880	39900	0
36*	67.70	5178.0	72	30.30	97537	0	3444	252	0	0	0.00	212	22.94	530	77.06	0	0.00	7	1.56	0	0.00	16.58	36	0	11880	39900	0
36*	72.91	5178.0	72	16.91	88902	0	3147	232	0	0	0.00	212	22.94	530	77.06	0	0.00	7	1.56	0	0.00	15.77	37	0	11880	39900	0

Table D.43: Results of all runs made with GBN network case 2, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.37	5566.0	62	39.78	9313	0	0	0	0	0	0.00	146	14.84	580	85.16	0	0.00	13	4.33	0	0.00	13.65	35	0	8260	47400	0
1	60.22	5576.0	58	1.67	9345	0	0	0	0	0	0.00	148	14.99	580	85.01	0	0.00	12	4.00	0	0.00	12.92	40	0	8360	47400	0
1	60.36	5574.0	60	15.37	9353	0	0	0	0	0	0.00	154	14.96	580	85.04	0	0.00	12	4.00	0	0.00	14.62	32	0	8340	47400	0
1	60.22	5572.0	65	13.18	9253	0	0	0	0	0	0.00	144	14.93	580	85.07	0	0.00	14	4.67	0	0.00	15.35	32	0	8320	47400	0
1	60.36	5574.0	60	59.65	9382	0	0	0	0	0	0.00	154	14.96	580	85.04	0	0.00	14	4.67	0	0.00	14.08	30	0	8340	47400	0
1	60.20	5570.0	62	52.71	9322	0	0	0	0	0	0.00	150	14.90	580	85.10	0	0.00	10	3.33	0	0.00	14.50	37	0	8300	47400	0
1	60.36	5570.0	60	22.20	9283	0	0	0	0	0	0.00	150	14.90	580	85.10	0	0.00	11	3.67	0	0.00	13.31	38	0	8300	47400	0
1	60.22	5570.0	61	58.41	9202	0	0	0	0	0	0.00	150	14.90	580	85.10	0	0.00	13	4.33	0	0.00	12.54	37	0	8300	47400	0
1	60.36	5574.0	64	57.67	9321	0	0	0	0	0	0.00	154	14.96	580	85.04	0	0.00	12	4.00	0	0.00	14.23	34	0	8340	47400	0
1	60.20	5572.0	54	23.32	9330	0	0	0	0	0	0.00	144	14.93	580	85.07	0	0.00	12	4.00	0	0.00	10.81	25	0	8320	47400	0
12	60.22	5566.0	57	50.58	93718	0	0	0	0	0	0.00	146	14.83	580	85.10	0	0.00	13	4.33	0	0.00	11.65	30	0	8260	47400	0
12	60.37	5570.0	61	58.50	91174	0	0	0	0	0	0.00	150	14.89	580	85.04	0	0.00	9	3.00	0	0.00	14.85	32	0	8300	47400	0
12	60.23	5570.0	58	5.99	93240	0	0	0	0	0	0.00	150	14.89	580	85.04	0	0.00	11	3.67	0	0.00	12.31	35	0	8300	47400	0
12	60.37	5566.0	63	22.34	84291	0	0	0	0	0	0.00	146	14.84	580	85.16	0	0.00	11	3.67	0	0.00	14.23	46	0	8260	47400	0
12	60.22	5570.0	64	51.20	87385	0	0	0	0	0	0.00	150	14.89	580	85.04	0	0.00	11	3.67	0	0.00	13.88	37	0	8300	47400	0
12	60.36	5566.0	61	59.92	92389	0	0	0	0	0	0.00	146	14.83	580	85.10	0	0.00	12	4.00	0	0.00	13.42	29	0	8260	47400	0
12	60.22	5566.0	56	46.91	87871	0	0	0	0	0	0.00	146	14.84	580	85.16	0	0.00	12	4.00	0	0.00	11.96	35	0	8260	47400	0
12	60.37	5570.0	57	17.80	91282	0	0	0	0	0	0.00	150	14.89	580	85.04	0	0.00	12	4.00	0	0.00	14.23	55	0	8300	47400	0
12	60.22	5566.0	57	2.40	89609	0	0	0	0	0	0.00	146	14.81	580	85.01	0	0.00	16	5.33	0	0.00	12.00	35	0	8260	47400	0
12	60.37	5570.0	60	51.78	87425	0	0	0	0	0	0.00	150	14.90	580	85.07	0	0.00	11	3.67	0	0.00	13.54	29	0	8300	47400	0
36	75.19	5570.0	57	53.45	120516	0	0	0	0	0	0.00	150	14.87	580	84.95	0	0.00	11	3.67	0	0.00	14.50	45	0	8300	47400	0
36	77.58	5570.0	58	32.14	122690	0	0	0	0	0	0.00	150	14.89	580	85.01	0	0.00	11	3.67	0	0.00	8.27	26	0	8300	47400	0
36	72.34	5570.0	60	35.87	115092	0	0	0	0	0	0.00	150	14.89	580	85.01	0	0.00	11	3.67	0	0.00	13.77	35	0	8300	47400	0
36	67.13	5566.0	58	37.10	107557	0	0	0	0	0	0.00	146	14.81	580	85.01	0	0.00	13	4.33	0	0.00	13.46	39	0	8260	47400	0
36	66.16	5570.0	60	56.38	106181	0	0	0	0	0	0.00	150	14.87	580	84.95	0	0.00	14	4.67	0	0.00	12.58	33	0	8300	47400	0
36	68.03	5566.0	63	30.39	107781	0	0	0	0	0	0.00	146	14.81	580	85.01	0	0.00	15	5.00	0	0.00	15.88	32	0	8260	47400	0
36	73.85	5570.0	57	6.99	117601	0	0	0	0	0	0.00	150	14.89	580	85.01	0	0.00	12	4.00	0	0.00	11.73	30	0	8300	47400	0
36	76.08	5566.0	60	39.77	117456	0	0	0	0	0	0.00	146	14.81	580	85.01	0	0.00	12	4.00	0	0.00	13.50	39	0	8260	47400	0
36	66.66	5570.0	56	47.46	105480	0	0	0	0	0	0.00	150	14.89	580	85.01	0	0.00	14	4.67	0	0.00	10.58	21	0	8300	47400	0
36	81.40	5570.0	56	14.41	129380	0	0	0	0	0	0.00	150	14.90	580	85.07	0	0.00	12	4.00	0	0.00	11.08	22	0	8300	47400	0
36*	60.90	5570.0	60	52.81	97462	0	0	0	0	0	0.00	150	14.90	580	85.10	0	0.00	13	4.33	0	0.00	11.58	33	0	8300	47400	0
36*	72.07	5566.0	63	54.15	110739	0	0	0	0	0	0.00	146	14.84	580	85.16	0	0.00	13	4.33	0	0.00	17.08	42	0	8260	47400	0
36*	74.30	5566.0	57	22.61	114750	0	0	0	0	0	0.00	146	14.84	580	85.16	0	0.00	16	5.33	0	0.00	12.00	35	0	8260	47400	0
36*	72.10	5570.0	57	46.52	110057	0	0	0	0	0	0.00	150	14.90	580	85.10	0	0.00	12	4.00	0	0.00	12.31	29	0	8300	47400	0
36*	67.98	5570.0	55	40.98	104631	0	0	0	0	0	0.00	150	14.90	580	85.10	0	0.00	12	4.00	0	0.00	9.69	35	0	8300	47400	0
36*	60.96	5570.0	58	35.08	95586	0	0	0	0	0	0.00	150	14.90	580	85.10	0	0.00	13	4.33	0	0.00	11.00	29	0	8300	47400	0
36*	74.02	5570.0	58	31.70	113665	0	0	0	0	0	0.00	150	14.90	580	85.10	0	0.00	12	4.00	0	0.00	11.62	31	0	8300	47400	0
36*	61.07	5566.0	63	24.43	95886	0	0	0	0	0	0.00	146	14.84	580	85.16	0	0.00	15	5.00	0	0.00	15.88	32	0	8260	47400	0
36*	68.48	5570.0	57	33.91	99374	0	0	0	0	0	0.00	150	14.90	580	85.10	0	0.00	12	4.00	0	0.00	11.73	30	0	8300	47400	0
36*	60.90	5570.0	58	3.20	98149	0	0	0	0	0	0.00	150	14.90	580	85.10	0	0.00	10	3.33	0	0.00	10.65	23	0	8300	47400	0

Table D.44: Results of all runs made with GBN network case 3, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.54	5696.0	78	8.72	4118	0	1881	268	0	0	0.00	544	49.44	336	50.56	0	0.00	25	2.31	0	0.00	13.38	31	0	28160	28800	0
1	60.36	5694.0	80	10.59	4116	0	1823	285	0	0	0.00	550	49.42	336	50.58	0	0.00	19	1.76	0	0.00	13.50	38	0	28140	28800	0
1	60.53	5694.0	80	45.77	4112	0	1835	257	0	0	0.00	550	49.42	336	50.58	0	0.00	22	2.04	0	0.00	12.85	40	0	28140	28800	0
1	60.34	5690.0	78	57.38	4073	0	1873	248	0	0	0.00	546	49.38	336	50.62	0	0.00	21	1.94	0	0.00	11.69	30	0	28100	28800	0
1	60.51	5696.0	79	23.24	4086	0	1824	264	0	0	0.00	544	49.44	336	50.56	0	0.00	21	1.94	0	0.00	12.73	32	0	28160	28800	0
1	60.34	5694.0	80	20.26	4101	0	1797	252	0	0	0.00	550	49.42	336	50.58	0	0.00	22	2.04	0	0.00	11.38	40	0	28140	28800	0
1	60.51	5696.0	77	28.35	4064	0	1769	234	0	0	0.00	544	49.44	336	50.56	0	0.00	21	1.94	0	0.00	12.00	33	0	28160	28800	0
1	60.53	5696.0	78	43.80	4092	0	1856	275	0	0	0.00	544	49.44	336	50.56	0	0.00	20	1.85	0	0.00	13.42	34	0	28160	28800	0
1	60.36	5694.0	78	40.78	4069	0	1867	249	0	0	0.00	550	49.42	336	50.58	0	0.00	20	1.85	0	0.00	12.92	34	0	28140	28800	0
1	60.51	5688.0	80	23.90	4061	0	1847	274	0	0	0.00	552	49.37	336	50.63	0	0.00	17	1.57	0	0.00	12.27	27	0	28080	28800	0
12	60.56	5690.0	77	17.83	40502	0	18107	2556	0	0	0.00	546	49.38	336	50.62	0	0.00	17	1.57	0	0.00	13.31	29	0	28100	28800	0
12	60.36	5684.0	78	6.96	39844	0	17803	2588	0	0	0.00	548	49.23	336	50.56	0	0.00	20	1.85	0	0.00	12.46	36	0	28040	28800	0
12	60.53	5686.0	80	27.16	36646	0	16295	2365	0	0	0.00	542	49.28	336	50.58	0	0.00	24	2.22	0	0.00	12.42	32	0	28060	28800	0
12	60.37	5690.0	79	56.50	39331	0	17554	2593	0	0	0.00	546	49.35	336	50.58	0	0.00	19	1.76	0	0.00	12.31	34	0	28100	28800	0
12	60.39	5690.0	80	26.88	41248	0	18413	2663	0	0	0.00	546	49.32	336	50.54	0	0.00	17	1.57	0	0.00	10.73	34	0	28100	28800	0
12	60.54	5690.0	77	59.67	40978	0	18144	2559	0	0	0.00	546	49.38	336	50.62	0	0.00	21	1.94	0	0.00	11.54	30	0	28100	28800	0
12	60.37	5688.0	78	52.20	40035	0	17719	2565	0	0	0.00	552	49.37	336	50.63	0	0.00	20	1.85	0	0.00	11.69	34	0	28080	28800	0
12	60.53	5690.0	77	9.14	40063	0	17985	2554	0	0	0.00	546	49.33	336	50.56	0	0.00	20	1.85	0	0.00	14.15	31	0	28100	28800	0
12	60.39	5686.0	77	31.70	40252	0	18011	2592	0	0	0.00	542	49.26	336	50.56	0	0.00	23	2.13	0	0.00	12.23	25	0	28060	28800	0
12	60.54	5690.0	79	21.33	37828	0	16855	2363	0	0	0.00	546	49.33	336	50.56	0	0.00	17	1.57	0	0.00	14.42	38	0	28100	28800	0
36	75.97	5688.0	77	20.55	48407	0	21752	3226	0	0	0.00	552	49.32	336	50.58	0	0.00	18	1.67	0	0.00	11.54	25	0	28080	28800	0
36	71.70	5690.0	77	49.65	47001	0	21021	2948	0	0	0.00	546	49.35	336	50.58	0	0.00	20	1.85	0	0.00	11.08	23	0	28100	28800	0
36	70.14	5686.0	78	33.99	45989	0	20582	3001	0	0	0.00	542	49.26	336	50.56	0	0.00	20	1.85	0	0.00	12.96	41	0	28060	28800	0
36	76.88	5688.0	79	43.57	52104	0	23225	3341	0	0	0.00	536	49.26	336	50.53	0	0.00	25	2.31	0	0.00	13.42	29	0	28080	28800	0
36	69.20	5690.0	80	32.12	45410	0	20171	2932	0	0	0.00	546	49.28	336	50.51	0	0.00	19	1.76	0	0.00	11.50	35	0	28100	28800	0
36	71.90	5688.0	80	42.51	45388	0	20231	2869	0	0	0.00	552	49.26	336	50.53	0	0.00	19	1.76	0	0.00	11.92	35	0	28080	28800	0
36	66.35	5690.0	77	28.08	41131	0	18237	2563	0	0	0.00	546	49.28	336	50.51	0	0.00	21	1.94	0	0.00	11.58	22	0	28100	28800	0
36	68.55	5690.0	77	43.70	45252	0	20157	2872	0	0	0.00	546	49.33	336	50.56	0	0.00	17	1.57	0	0.00	12.92	33	0	28100	28800	0
36	69.03	5686.0	80	23.65	43797	0	19670	2805	0	0	0.00	542	49.31	336	50.62	0	0.00	20	1.85	0	0.00	12.54	34	0	28060	28800	0
36	74.27	5690.0	78	6.86	47535	0	21119	3017	0	0	0.00	546	49.26	336	50.49	0	0.00	21	1.94	0	0.00	11.50	26	0	28100	28800	0
36*	61.01	5684.0	77	21.84	41924	0	18637	2596	0	0	0.00	548	49.33	336	50.67	0	0.00	21	1.94	0	0.00	12.85	28	0	28040	28800	0
36*	61.40	5684.0	78	13.96	40148	0	17934	2575	0	0	0.00	548	49.33	336	50.67	0	0.00	20	1.85	0	0.00	12.46	36	0	28040	28800	0
36*	61.14	5692.0	76	7.71	42403	0	18785	2734	0	0	0.00	540	49.40	336	50.60	0	0.00	22	2.04	0	0.00	15.58	35	0	28120	28800	0
36*	61.03	5690.0	78	10.00	41875	0	18667	2600	0	0	0.00	546	49.38	336	50.62	0	0.00	22	2.04	0	0.00	12.69	27	0	28100	28800	0
36*	61.01	5688.0	78	48.77	42053	0	18771	2675	0	0	0.00	552	49.37	336	50.63	0	0.00	20	1.85	0	0.00	11.69	34	0	28080	28800	0
36*	65.13	5688.0	77	42.56	43643	0	19316	2763	0	0	0.00	552	49.37	336	50.63	0	0.00	21	1.94	0	0.00	11.85	27	0	28080	28800	0
36*	73.07	5688.0	79	41.90	43637	0	19431	2815	0	0	0.00	552	49.37	336	50.63	0	0.00	19	1.76	0	0.00	14.58	32	0	28080	28800	0
36*	60.92	5690.0	77	45.71	42112	0	18957	2659	0	0	0.00	546	49.38	336	50.62	0	0.00	20	1.85	0	0.00	11.08	23	0	28100	28800	0
36*	61.20	5690.0	80	7.25	42414	0	19058	2759	0	0	0.00	546	49.38	336	50.62	0	0.00	24	2.22	0	0.00	11.77	33	0	28100	28800	0
36*	68.69	5688.0	79	55.57	42197	0	18942	2714	0	0	0.00	536	49.37	336	50.63	0	0.00	25	2.31	0	0.00	13.42	29	0	28080	28800	0

Table D.45: Results of all runs made with GBN network case 4, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.37	6236.0	79	55.66	3468	0	2963	212	0	0	0.00	264	23.22	636	76.78	0	0.00	18	3.33	0	0.00	11.69	38	0	14480	47880	0
1	60.56	6234.0	79	37.55	3455	0	2961	198	0	0	0.00	254	23.20	636	76.80	0	0.00	13	2.41	0	0.00	14.38	45	0	14460	47880	0
1	60.36	6234.0	79	39.00	3417	0	2939	199	0	0	0.00	254	23.20	636	76.80	0	0.00	15	2.78	0	0.00	11.65	34	0	14460	47880	0
1	60.54	6240.0	77	18.17	3410	0	2953	210	0	0	0.00	252	23.27	636	76.73	0	0.00	15	2.78	0	0.00	12.35	35	0	14520	47880	0
1	60.36	6238.0	78	3.07	3472	0	2937	221	0	0	0.00	258	23.24	636	76.76	0	0.00	16	2.96	0	0.00	12.23	34	0	14500	47880	0
1	60.56	6232.0	79	1.45	3426	0	2954	199	0	0	0.00	260	23.17	636	76.83	0	0.00	14	2.59	0	0.00	11.81	30	0	14440	47880	0
1	60.34	6238.0	80	30.05	3444	0	2969	181	0	0	0.00	258	23.24	636	76.76	0	0.00	14	2.59	0	0.00	11.77	31	0	14500	47880	0
1	60.54	6234.0	78	10.56	3404	0	2921	195	0	0	0.00	254	23.20	636	76.80	0	0.00	15	2.78	0	0.00	10.96	27	0	14460	47880	0
1	60.36	6234.0	80	38.78	3400	0	2914	196	0	0	0.00	254	23.20	636	76.80	0	0.00	14	2.59	0	0.00	8.65	39	0	14460	47880	0
1	60.54	6228.0	79	13.93	3419	0	2945	204	0	0	0.00	272	23.12	636	76.88	0	0.00	17	3.15	0	0.00	12.31	35	0	14400	47880	0
12	60.54	6232.0	78	37.75	33375	0	28769	2026	0	0	0.00	260	23.14	636	76.73	0	0.00	15	2.78	0	0.00	13.81	34	0	14440	47880	0
12	60.37	6226.0	79	22.60	33109	0	28444	2033	0	0	0.00	262	23.10	636	76.90	0	0.00	14	2.59	0	0.00	11.92	33	0	14380	47880	0
12	60.54	6230.0	80	39.12	34909	0	30007	2059	0	0	0.00	266	23.12	636	76.78	0	0.00	15	2.78	0	0.00	10.35	42	0	14420	47880	0
12	70.61	6228.0	78	13.28	33993	0	29140	2058	0	0	0.00	256	23.09	636	76.78	0	0.00	16	2.96	0	0.00	13.04	33	0	14400	47880	0
12	60.48	6228.0	80	30.69	30859	0	26427	1860	0	0	0.00	256	23.08	636	76.76	0	0.00	14	2.59	0	0.00	12.19	39	0	14400	47880	0
12	60.50	6228.0	78	45.07	33588	0	28837	1984	0	0	0.00	256	23.11	636	76.83	0	0.00	14	2.59	0	0.00	12.88	33	0	14400	47880	0
12	60.59	6232.0	79	0.59	32168	0	27505	1878	0	0	0.00	260	23.15	636	76.76	0	0.00	14	2.59	0	0.00	12.35	39	0	14440	47880	0
12	60.40	6230.0	80	14.32	30914	0	26518	1843	0	0	0.00	250	23.10	636	76.71	0	0.00	14	2.59	0	0.00	10.00	34	0	14420	47880	0
12	60.56	6232.0	79	19.34	33382	0	28627	1986	0	0	0.00	260	23.15	636	76.76	0	0.00	17	3.15	0	0.00	12.88	40	0	14440	47880	0
12	60.39	6228.0	78	35.68	32870	0	28154	1993	0	0	0.00	256	23.08	636	76.76	0	0.00	15	2.78	0	0.00	12.35	45	0	14400	47880	0
36	72.38	6228.0	78	16.79	42115	0	36337	2526	0	0	0.00	256	23.06	636	76.68	0	0.00	17	3.15	0	0.00	10.65	29	0	14400	47880	0
36	73.44	6230.0	78	0.41	42392	0	36411	2524	0	0	0.00	250	23.15	636	76.85	0	0.00	16	2.96	0	0.00	10.62	25	0	14420	47880	0
36	70.23	6228.0	78	50.20	40593	0	34867	2405	0	0	0.00	256	23.07	636	76.71	0	0.00	14	2.59	0	0.00	13.23	34	0	14400	47880	0
36	74.12	6228.0	78	57.60	42500	0	36485	2591	0	0	0.00	256	23.06	636	76.68	0	0.00	13	2.41	0	0.00	11.35	26	0	14400	47880	0
36	71.87	6228.0	80	37.88	41464	165	35566	2641	0	0	0.00	256	23.06	636	76.68	0	0.00	13	2.41	0	0.00	10.12	28	0	14400	47880	0
36	74.86	6230.0	78	20.37	43717	0	37626	2617	0	0	0.00	250	23.09	636	76.68	0	0.00	16	2.96	0	0.00	11.77	29	0	14420	47880	0
36	82.07	6232.0	80	25.02	45213	0	38798	2684	0	0	0.00	244	23.14	636	76.73	0	0.00	13	2.41	0	0.00	12.81	29	0	14440	47880	0
36	68.20	6232.0	78	38.11	38771	0	33300	2331	0	0	0.00	244	23.13	636	76.71	0	0.00	14	2.59	0	0.00	10.00	33	0	14440	47880	0
36	69.08	6230.0	79	46.96	38803	0	33323	2318	0	0	0.00	250	23.09	636	76.68	0	0.00	14	2.59	0	0.00	11.88	38	0	14420	47880	0
36	79.25	6232.0	79	41.48	45393	0	38951	2766	0	0	0.00	260	23.14	636	76.73	0	0.00	17	3.15	0	0.00	13.15	36	0	14440	47880	0
36*	61.29	6228.0	80	48.28	34071	0	29253	2054	0	0	0.00	256	23.12	636	76.88	0	0.00	14	2.59	0	0.00	12.08	34	0	14400	47880	0
36*	61.60	6228.0	80	13.04	36099	0	30883	2198	0	0	0.00	256	23.12	636	76.88	0	0.00	15	2.78	0	0.00	11.65	37	0	14400	47880	0
36*	61.25	6228.0	78	17.46	35114	0	30279	2106	0	0	0.00	256	23.12	636	76.88	0	0.00	17	3.15	0	0.00	10.65	29	0	14400	47880	0
36*	61.25	6230.0	80	17.74	35021	0	30137	2114	0	0	0.00	250	23.15	636	76.85	0	0.00	14	2.59	0	0.00	12.96	41	0	14420	47880	0
36*	61.01	6234.0	78	0.58	35172	0	30240	2103	0	0	0.00	254	23.20	636	76.80	0	0.00	17	3.15	0	0.00	13.92	45	0	14460	47880	0
36*	61.14	6228.0	78	51.12	35659	0	30627	2136	0	0	0.00	256	23.12	636	76.88	0	0.00	14	2.59	0	0.00	13.23	34	0	14400	47880	0
36*	61.14	6228.0	79	15.32	34992	0	30171	2128	0	0	0.00	256	23.12	636	76.88	0	0.00	15	2.78	0	0.00	12.85	45	0	14400	47880	0
36*	61.31	6234.0	78	16.85	34772	0	29877	2100	0	0	0.00	254	23.20	636	76.80	0	0.00	15	2.78	0	0.00	11.27	32	0	14460	47880	0
36*	61.43	6232.0	79	54.94	35399	0	30497	2208	0	0	0.00	260	23.17	636	76.83	0	0.00	17	3.15	0	0.00	10.54	30	0	14440	47880	0
36*	74.74	6230.0	78	16.51	35809	0	30759	2138	0	0	0.00	250	23.15	636	76.85	0	0.00	16	2.96	0	0.00	11.77	29	0	14420	47880	0

Table D.46: Results of all runs made with GBN network case 5, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.47	6702.0	74	32.48	4346	0	38	0	0	0	0.00	190	15.13	696	84.87	0	0.00	21	5.83	0	0.00	13.62	29	0	10140	56880	0
1	60.28	6712.0	70	34.68	4332	0	34	0	0	0	0.00	192	15.26	696	84.74	0	0.00	21	5.83	0	0.00	12.23	26	0	10240	56880	0
1	60.48	6708.0	73	27.36	4351	0	26	0	0	0	0.00	188	15.21	696	84.79	0	0.00	20	5.56	0	0.00	11.50	28	0	10200	56880	0
1	60.26	6712.0	69	29.30	4306	0	45	0	0	0	0.00	192	15.26	696	84.74	0	0.00	18	5.00	0	0.00	11.19	28	0	10240	56880	0
1	60.48	6712.0	72	15.44	4319	0	32	0	0	0	0.00	192	15.26	696	84.74	0	0.00	21	5.83	0	0.00	11.85	28	0	10240	56880	0
1	60.26	6708.0	70	35.55	4385	0	24	0	0	0	0.00	188	15.21	696	84.79	0	0.00	20	5.56	0	0.00	12.00	23	0	10200	56880	0
1	60.47	6706.0	74	30.92	4352	0	32	0	0	0	0.00	194	15.18	696	84.82	0	0.00	24	6.67	0	0.00	12.73	45	0	10180	56880	0
1	60.29	6712.0	75	39.11	4343	0	28	0	0	0	0.00	192	15.26	696	84.74	0	0.00	21	5.83	0	0.00	12.58	33	0	10240	56880	0
1	60.47	6710.0	70	21.50	4344	0	33	0	0	0	0.00	198	15.23	696	84.77	0	0.00	23	6.39	0	0.00	11.58	23	0	10220	56880	0
1	60.25	6712.0	71	46.77	4367	0	29	0	0	0	0.00	192	15.26	696	84.74	0	0.00	23	6.39	0	0.00	11.77	35	0	10240	56880	0
12	60.29	6706.0	79	22.64	44744	0	345	0	0	0	0.00	194	15.17	696	84.74	0	0.00	22	6.11	0	0.00	9.65	29	0	10180	56880	0
12	60.26	6704.0	77	35.76	43937	0	342	0	0	0	0.00	200	15.14	696	84.74	0	0.00	23	6.39	0	0.00	11.88	29	0	10160	56880	0
12	60.28	6708.0	69	56.92	46368	0	339	0	0	0	0.00	188	15.20	696	84.74	0	0.00	20	5.56	0	0.00	11.62	24	0	10200	56880	0
12	60.50	6702.0	76	23.93	43824	0	317	0	0	0	0.00	190	15.11	696	84.74	0	0.00	22	6.11	0	0.00	12.69	31	0	10140	56880	0
12	60.29	6702.0	75	36.32	43930	0	357	0	0	0	0.00	190	15.11	696	84.74	0	0.00	21	5.83	0	0.00	10.77	26	0	10140	56880	0
12	60.48	6706.0	72	29.24	45499	0	362	0	0	0	0.00	194	15.17	696	84.77	0	0.00	20	5.56	0	0.00	11.69	28	0	10180	56880	0
12	60.29	6706.0	75	43.98	44587	0	377	0	0	0	0.00	194	15.18	696	84.82	0	0.00	19	5.28	0	0.00	13.42	31	0	10180	56880	0
12	60.48	6702.0	72	56.24	43945	0	366	0	0	0	0.00	190	15.12	696	84.79	0	0.00	25	6.94	0	0.00	11.73	24	0	10140	56880	0
12	60.29	6706.0	72	20.17	45839	0	363	0	0	0	0.00	194	15.17	696	84.74	0	0.00	24	6.67	0	0.00	11.38	24	0	10180	56880	0
12	60.48	6702.0	75	10.06	44501	0	352	0	0	0	0.00	190	15.11	696	84.74	0	0.00	19	5.28	0	0.00	13.12	34	0	10140	56880	0
36	72.96	6706.0	71	47.92	55526	0	478	0	0	0	0.00	194	15.16	696	84.69	0	0.00	20	5.56	0	0.00	12.54	29	0	10180	56880	0
36	72.21	6702.0	71	11.15	54230	0	475	0	0	0	0.00	190	15.10	696	84.72	0	0.00	21	5.83	0	0.00	12.81	32	0	10140	56880	0
36	66.74	6700.0	73	57.95	51936	0	411	0	0	0	0.00	196	15.06	696	84.67	0	0.00	20	5.56	0	0.00	13.73	32	0	10120	56880	0
36	75.10	6702.0	69	47.44	56721	0	503	0	0	0	0.00	190	15.08	696	84.62	0	0.00	24	6.67	0	0.00	10.65	31	0	10140	56880	0
36	70.40	6708.0	73	47.80	54608	0	434	0	0	0	0.00	188	15.21	696	84.79	0	0.00	22	6.11	0	0.00	12.92	34	0	10200	56880	0
36	75.55	6702.0	74	54.30	57474	0	486	0	0	0	0.00	190	15.09	696	84.67	0	0.00	22	6.11	0	0.00	10.58	27	0	10140	56880	0
36	74.83	6706.0	72	33.20	56810	0	487	0	0	0	0.00	194	15.15	696	84.67	0	0.00	24	6.67	0	0.00	10.65	33	0	10180	56880	0
36	66.99	6706.0	72	55.26	51355	0	411	0	0	0	0.00	194	15.15	696	84.64	0	0.00	19	5.28	0	0.00	12.04	39	0	10180	56880	0
36	66.41	6706.0	76	44.57	50660	0	444	0	0	0	0.00	194	15.15	696	84.64	0	0.00	21	5.83	0	0.00	13.08	36	0	10180	56880	0
36	67.67	6702.0	75	55.52	50925	0	382	0	0	0	0.00	190	15.09	696	84.67	0	0.00	20	5.56	0	0.00	12.35	26	0	10140	56880	0
36*	60.86	6706.0	73	36.85	47305	0	343	0	0	0	0.00	194	15.18	696	84.82	0	0.00	21	5.83	0	0.00	13.38	39	0	10180	56880	0
36*	61.42	6708.0	69	55.82	47518	0	362	0	0	0	0.00	188	15.21	696	84.79	0	0.00	20	5.56	0	0.00	11.62	24	0	10200	56880	0
36*	60.93	6708.0	72	17.61	46444	0	367	0	0	0	0.00	188	15.21	696	84.79	0	0.00	19	5.28	0	0.00	12.96	26	0	10200	56880	0
36*	77.10	6702.0	72	39.92	48130	0	407	0	0	0	0.00	190	15.13	696	84.87	0	0.00	20	5.56	0	0.00	13.50	24	0	10140	56880	0
36*	61.06	6706.0	77	48.55	46144	0	347	0	0	0	0.00	194	15.18	696	84.82	0	0.00	21	5.83	0	0.00	12.12	33	0	10180	56880	0
36*	75.00	6708.0	73	34.93	51373	0	408	0	0	0	0.00	188	15.21	696	84.79	0	0.00	22	6.11	0	0.00	12.65	30	0	10200	56880	0
36*	60.95	6702.0	74	58.41	43004	0	333	0	0	0	0.00	190	15.13	696	84.87	0	0.00	19	5.28	0	0.00	12.65	34	0	10140	56880	0
36*	61.06	6706.0	70	42.17	47023	0	364	0	0	0	0.00	194	15.18	696	84.82	0	0.00	26	7.22	0	0.00	11.88	29	0	10180	56880	0
36*	61.32	6702.0	74	52.46	48290	0	373	0	0	0	0.00	190	15.13	696	84.87	0	0.00	22	6.11	0	0.00	12.42	35	0	10140	56880	0
36*	69.54	6706.0	72	21.53	48567	0	399	0	0	0	0.00	194	15.18	696	84.82	0	0.00	20	5.56	0	0.00	12.27	32	0	10180	56880	0

Table D.47: Results of all runs made with GBN network case 6, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.30	6636.0	80	9.05	2086	0	2086	1395	0	0	0.00	564	49.73	388	50.27	0	0.00	27	2.17	0	0.00	10.92	33	0	33000	33360	0
1	60.55	6626.0	80	24.18	2009	0	2009	1288	0	0	0.00	562	49.65	388	50.35	0	0.00	28	2.25	0	0.00	10.04	28	0	32900	33360	0
1	60.28	6630.0	80	18.86	2094	0	2094	1392	0	0	0.00	582	49.68	388	50.32	0	0.00	27	2.17	0	0.00	8.12	23	0	32940	33360	0
1	60.55	6630.0	80	38.63	2121	0	2121	1426	0	0	0.00	566	49.68	388	50.32	0	0.00	28	2.25	0	0.00	10.92	27	0	32940	33360	0
1	60.30	6622.0	80	53.54	2082	0	2082	1378	0	0	0.00	574	49.62	388	50.38	0	0.00	28	2.25	0	0.00	8.96	28	0	32860	33360	0
1	60.53	6638.0	80	9.33	2104	0	2104	1410	0	0	0.00	574	49.74	388	50.26	0	0.00	35	2.82	0	0.00	7.42	22	0	33020	33360	0
1	60.31	6634.0	80	15.85	2108	0	2108	1388	0	0	0.00	570	49.71	388	50.29	0	0.00	28	2.25	0	0.00	9.77	40	0	32980	33360	0
1	60.58	6626.0	80	39.81	2122	0	2122	1417	0	0	0.00	562	49.65	388	50.35	0	0.00	25	2.01	0	0.00	10.42	34	0	32900	33360	0
1	60.29	6632.0	80	58.52	2127	0	2127	1412	0	0	0.00	576	49.70	388	50.30	0	0.00	31	2.50	0	0.00	9.35	30	0	32960	33360	0
1	60.54	6626.0	80	17.71	2058	0	2058	1349	0	0	0.00	562	49.65	388	50.35	0	0.00	34	2.74	0	0.00	9.23	31	0	32900	33360	0
12	60.61	6608.0	80	39.02	21699	0	21699	14359	0	0	0.00	568	49.32	388	50.29	0	0.00	27	2.17	0	0.00	8.12	26	0	32720	33360	0
12	60.36	6616.0	80	51.06	21482	0	21482	14187	0	0	0.00	560	49.44	388	50.29	0	0.00	25	2.01	0	0.00	8.27	25	0	32800	33360	0
12	60.59	6614.0	80	58.80	20178	0	20178	13414	0	0	0.00	566	49.38	388	50.26	0	0.00	30	2.42	0	0.00	8.81	23	0	32780	33360	0
12	60.40	6604.0	80	47.46	20478	0	20478	13481	0	0	0.00	564	49.26	388	50.29	0	0.00	23	1.85	0	0.00	10.00	32	0	32680	33360	0
12	60.62	6606.0	80	57.14	20444	0	20444	13563	0	0	0.00	574	49.35	388	50.35	0	0.00	31	2.50	0	0.00	10.46	36	0	32700	33360	0
12	60.34	6616.0	80	36.02	21168	0	21168	13925	0	0	0.00	560	49.46	388	50.30	0	0.00	28	2.25	0	0.00	9.08	30	0	32800	33360	0
12	60.62	6626.0	80	30.84	19638	0	19638	13024	0	0	0.00	562	49.56	388	50.26	0	0.00	32	2.58	0	0.00	8.08	31	0	32900	33360	0
12	60.37	6614.0	80	37.92	19614	0	19614	12941	0	0	0.00	566	49.49	388	50.36	0	0.00	26	2.09	0	0.00	9.69	36	0	32780	33360	0
12	60.61	6614.0	80	1.12	20890	0	20890	13738	0	0	0.00	566	49.47	388	50.35	0	0.00	28	2.25	0	0.00	10.15	34	0	32780	33360	0
12	60.39	6616.0	80	48.20	20429	0	20429	13497	0	0	0.00	560	49.47	388	50.32	0	0.00	27	2.17	0	0.00	9.54	31	0	32800	33360	0
36	73.51	6618.0	80	9.28	22489	0	22489	14853	0	0	0.00	570	49.40	388	50.21	0	0.00	30	2.42	0	0.00	9.96	26	0	32820	33360	0
36	74.94	6618.0	80	19.34	24571	0	24571	16178	0	0	0.00	554	49.31	388	50.12	0	0.00	27	2.17	0	0.00	10.35	37	0	32820	33360	0
36	78.06	6610.0	80	55.04	25733	0	25733	17094	0	0	0.00	562	49.47	388	50.41	0	0.00	29	2.33	0	0.00	10.38	27	0	32740	33360	0
36	66.85	6624.0	80	29.30	22359	0	22359	14646	0	0	0.00	568	49.47	388	50.20	0	0.00	28	2.25	0	0.00	10.27	33	0	32880	33360	0
36	73.13	6610.0	80	0.53	24032	0	24032	15826	0	0	0.00	562	49.37	388	50.30	0	0.00	28	2.25	0	0.00	10.50	29	0	32740	33360	0
36	75.25	6620.0	80	54.49	26115	0	26115	17310	0	0	0.00	564	49.43	388	50.21	0	0.00	33	2.66	0	0.00	9.85	31	0	32840	33360	0
36	69.33	6606.0	80	46.36	22625	0	22625	14938	0	0	0.00	558	49.35	388	50.35	0	0.00	27	2.17	0	0.00	12.19	42	0	32700	33360	0
36	76.94	6622.0	80	50.75	24993	0	24993	16434	0	0	0.00	574	49.59	388	50.35	0	0.00	28	2.25	0	0.00	7.50	31	0	32860	33360	0
36	74.38	6608.0	80	4.45	25094	0	25094	16561	0	0	0.00	568	49.22	388	50.18	0	0.00	25	2.01	0	0.00	10.19	31	0	32720	33360	0
36	67.00	6612.0	80	18.16	21950	0	21950	14455	0	0	0.00	556	49.37	388	50.27	0	0.00	25	2.01	0	0.00	9.31	33	0	32760	33360	0
36*	60.96	6614.0	80	10.86	20868	0	20868	13695	0	0	0.00	566	49.56	388	50.44	0	0.00	32	2.58	0	0.00	10.54	31	0	32780	33360	0
36*	61.21	6612.0	80	17.19	22296	0	22296	14779	0	0	0.00	572	49.55	388	50.45	0	0.00	34	2.74	0	0.00	9.58	30	0	32760	33360	0
36*	61.14	6620.0	80	31.61	20709	0	20709	13833	0	0	0.00	564	49.61	388	50.39	0	0.00	30	2.42	0	0.00	10.04	36	0	32840	33360	0
36*	61.53	6606.0	80	28.81	20399	0	20399	13460	0	0	0.00	574	49.50	388	50.50	0	0.00	28	2.25	0	0.00	10.27	25	0	32700	33360	0
36*	61.00	6620.0	80	0.47	20966	0	20966	13718	0	0	0.00	564	49.61	388	50.39	0	0.00	31	2.50	0	0.00	8.46	24	0	32840	33360	0
36*	61.23	6620.0	80	33.12	21625	0	21625	14244	0	0	0.00	564	49.61	388	50.39	0	0.00	30	2.42	0	0.00	9.54	32	0	32840	33360	0
36*	61.20	6610.0	80	29.52	22091	0	22091	14602	0	0	0.00	562	49.53	388	50.47	0	0.00	25	2.01	0	0.00	8.69	25	0	32740	33360	0
36*	65.63	6616.0	80	2.09	22518	0	22518	14827	0	0	0.00	560	49.58	388	50.42	0	0.00	30	2.42	0	0.00	10.31	30	0	32800	33360	0
36*	61.15	6620.0	80	33.32	20730	0	20730	13695	0	0	0.00	564	49.61	388	50.39	0	0.00	26	2.09	0	0.00	9.92	27	0	32840	33360	0
36*	61.31	6618.0	80	22.81	21914	0	21914	14451	0	0	0.00	570	49.59	388	50.41	0	0.00	26	2.09	0	0.00	10.77	39	0	32820	33360	0

Table D.48: Results of all runs made with GBN network case 7, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.51	7280.0	80	28.17	1338	0	1338	296	0	0	0.00	294	23.93	734	76.07	0	0.00	27	4.35	0	0.00	7.54	30	0	17420	55380	0
1	60.56	7284.0	80	54.33	1318	0	1318	284	0	0	0.00	298	23.97	734	76.03	0	0.00	29	4.67	0	0.00	5.35	21	0	17460	55380	0
1	60.37	7280.0	80	40.22	1355	0	1355	301	0	0	0.00	294	23.93	734	76.07	0	0.00	28	4.51	0	0.00	5.69	25	0	17420	55380	0
1	60.56	7274.0	80	12.25	1346	0	1346	305	0	0	0.00	296	23.87	734	76.13	0	0.00	30	4.83	0	0.00	6.77	21	0	17360	55380	0
1	60.31	7260.0	80	16.72	1353	0	1353	314	0	0	0.00	290	23.72	734	76.28	0	0.00	29	4.67	0	0.00	4.73	16	0	17220	55380	0
1	60.61	7278.0	80	25.02	1342	0	1342	305	0	0	0.00	300	23.91	734	76.09	0	0.00	32	5.15	0	0.00	5.88	21	0	17400	55380	0
1	60.33	7274.0	80	25.01	1358	0	1358	318	0	0	0.00	280	23.87	734	76.13	0	0.00	32	5.15	0	0.00	9.35	30	0	17360	55380	0
1	60.57	7268.0	80	20.51	1360	0	1360	313	0	0	0.00	298	23.80	734	76.20	0	0.00	33	5.31	0	0.00	7.46	30	0	17300	55380	0
1	60.33	7268.0	80	22.04	1373	0	1373	322	0	0	0.00	298	23.80	734	76.20	0	0.00	28	4.51	0	0.00	6.85	31	0	17300	55380	0
1	60.56	7260.0	80	39.66	1371	0	1371	339	0	0	0.00	290	23.72	734	76.28	0	0.00	26	4.19	0	0.00	7.69	24	0	17220	55380	0
12	60.70	7264.0	80	2.34	11183	0	11182	2557	0	0	0.00	294	23.72	734	76.09	0	0.00	29	4.67	0	0.00	6.19	31	0	17260	55380	0
12	60.39	7258.0	80	4.10	8346	0	8346	1931	0	0	0.00	296	23.63	734	76.07	0	0.00	28	4.51	0	0.00	6.46	24	0	17200	55380	0
12	60.70	7260.0	80	21.06	10647	0	10646	2514	0	0	0.00	290	23.69	734	76.20	0	0.00	29	4.67	0	0.00	7.69	31	0	17220	55380	0
12	60.37	7262.0	80	3.32	9182	0	9181	2066	0	0	0.00	300	23.69	734	76.11	0	0.00	28	4.51	0	0.00	7.08	24	0	17240	55380	0
12	60.67	7258.0	80	45.49	10323	0	10323	2409	0	0	0.00	296	23.69	734	76.28	0	0.00	28	4.51	0	0.00	7.08	22	0	17200	55380	0
12	60.43	7254.0	80	6.76	10065	0	10065	2294	0	0	0.00	292	23.56	734	76.03	0	0.00	25	4.03	0	0.00	6.08	23	0	17160	55380	0
12	60.64	7264.0	80	8.28	12136	0	12135	2871	0	0	0.00	294	23.73	734	76.13	0	0.00	24	3.86	0	0.00	6.92	24	0	17260	55380	0
12	60.65	7262.0	80	29.97	9378	0	9378	2129	0	0	0.00	300	23.68	734	76.07	0	0.00	29	4.67	0	0.00	6.15	20	0	17240	55380	0
12	60.51	7264.0	80	56.25	12190	0	12190	2905	0	0	0.00	294	23.72	734	76.11	0	0.00	29	4.67	0	0.00	8.08	27	0	17260	55380	0
12	60.64	7262.0	80	54.48	10969	0	10969	2513	0	0	0.00	300	23.69	734	76.09	0	0.00	28	4.51	0	0.00	5.54	20	0	17240	55380	0
36	73.83	7256.0	80	6.88	15545	0	15544	3624	0	0	0.00	302	23.61	734	76.09	0	0.00	25	4.03	0	0.00	7.62	27	0	17180	55380	0
36	72.04	7262.0	80	12.06	14633	0	14632	3368	0	0	0.00	300	23.64	734	75.95	0	0.00	26	4.19	0	0.00	6.73	20	0	17240	55380	0
36	74.63	7262.0	80	22.28	14890	0	14889	3408	0	0	0.00	300	23.63	734	75.90	0	0.00	25	4.03	0	0.00	7.23	23	0	17240	55380	0
36	66.50	7254.0	80	59.69	13991	0	13989	3200	0	0	0.00	292	23.57	734	76.07	0	0.00	25	4.03	0	0.00	8.73	31	0	17160	55380	0
36	66.49	7238.0	80	51.32	14757	0	14757	3483	0	0	0.00	292	23.31	734	75.95	0	0.00	27	4.35	0	0.00	8.77	29	0	17000	55380	0
36	76.02	7260.0	80	27.82	14578	0	14578	3304	0	0	0.00	290	23.63	734	76.01	0	0.00	29	4.67	0	0.00	8.04	25	0	17220	55380	0
36	69.37	7260.0	80	38.63	15142	0	15142	3390	0	0	0.00	290	23.62	734	75.97	0	0.00	27	4.35	0	0.00	8.27	36	0	17220	55380	0
36	76.02	7260.0	80	19.62	15445	0	15445	3586	0	0	0.00	290	23.67	734	76.13	0	0.00	29	4.67	0	0.00	4.73	16	0	17220	55380	0
36	69.01	7228.0	80	3.85	13948	0	13948	3221	0	0	0.00	290	23.23	734	76.13	0	0.00	27	4.35	0	0.00	6.73	24	0	16900	55380	0
36	73.91	7251.6	80	40.33	14115	0	14114	3308	0	0	0.00	296	23.37	734	75.95	1	0.13	25	4.03	0	0.00	6.42	19	0	17040	55380	96
36*	61.12	7258.0	80	34.43	14696	0	14696	3447	0	0	0.00	296	23.70	734	76.30	0	0.00	30	4.83	0	0.00	8.23	35	0	17200	55380	0
36*	61.34	7260.0	80	16.02	14105	0	14105	3240	0	0	0.00	306	23.72	734	76.28	0	0.00	27	4.35	0	0.00	6.85	27	0	17220	55380	0
36*	61.07	7258.0	80	18.16	14264	0	14263	3264	0	0	0.00	296	23.70	734	76.30	0	0.00	28	4.51	0	0.00	8.50	26	0	17200	55380	0
36*	61.53	7258.0	80	16.04	14603	0	14603	3464	0	0	0.00	296	23.70	734	76.30	0	0.00	22	3.54	0	0.00	6.19	26	0	17200	55380	0
36*	61.45	7250.0	80	51.26	13721	0	13719	3182	0	0	0.00	288	23.61	734	76.39	0	0.00	24	3.86	0	0.00	6.77	19	0	17120	55380	0
36*	61.14	7270.0	80	22.31	14325	0	14325	3387	0	0	0.00	292	23.82	734	76.18	0	0.00	27	4.35	0	0.00	7.08	25	0	17320	55380	0
36*	76.32	7256.0	80	33.84	15334	0	15333	3539	0	0	0.00	302	23.68	734	76.32	0	0.00	25	4.03	0	0.00	7.62	27	0	17180	55380	0
36*	61.06	7246.0	80	34.12	14055	0	14054	3238	0	0	0.00	284	23.57	734	76.43	0	0.00	26	4.19	0	0.00	6.88	26	0	17080	55380	0
36*	74.24	7264.0	80	18.38	17421	0	17420	4020	0	0	0.00	294	23.76	734	76.24	0	0.00	28	4.51	0	0.00	8.23	27	0	17260	55380	0
36*	61.29	7260.0	80	11.62	14202	0	14201	3264	0	0	0.00	290	23.72	734	76.28	0	0.00	27	4.35	0	0.00	8.08	25	0	17220	55380	0

Table D.49: Results of all runs made with GBN network case 8, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.34	7960.0	80	58.06	733	0	733	1	0	0	0.00	240	23.34	726	76.66	0	0.00	42	10.14	0	0.00	9.38	36	0	18580	61020	0
1	60.31	7968.0	80	44.69	737	0	737	0	0	0	0.00	234	22.52	738	77.48	0	0.00	36	8.70	0	0.00	10.69	35	0	17940	61740	0
1	60.65	7968.0	80	41.65	748	0	748	0	0	0	0.00	242	22.97	732	77.03	0	0.00	35	8.45	0	0.00	9.35	38	0	18300	61380	0
1	60.36	7976.0	80	13.40	740	0	740	0	0	0	0.00	250	23.80	722	76.20	0	0.00	37	8.94	0	0.00	11.96	40	0	18980	60780	0
1	60.62	7976.0	80	45.99	737	0	737	0	0	0	0.00	236	22.89	734	77.11	0	0.00	38	9.18	0	0.00	10.08	36	0	18260	61500	0
1	60.40	7968.0	80	19.06	737	0	737	1	0	0	0.00	238	23.12	730	76.88	0	0.00	41	9.90	0	0.00	7.62	30	0	18420	61260	0
1	60.62	7980.0	80	8.92	733	0	733	0	0	0	0.00	248	23.38	728	76.62	0	0.00	38	9.18	0	0.00	12.15	45	0	18660	61140	0
1	60.36	7976.0	80	1.70	744	0	744	0	0	0	0.00	246	23.19	730	76.81	0	0.00	39	9.42	0	0.00	11.38	38	0	18500	61260	0
1	60.59	7972.0	80	42.50	748	0	748	0	0	0	0.00	242	23.16	730	76.84	0	0.00	42	10.14	0	0.00	10.58	42	0	18460	61260	0
1	60.36	7958.0	80	13.01	747	0	747	0	0	0	0.00	240	23.62	722	76.38	0	0.00	34	8.21	0	0.00	10.12	39	0	18800	60780	0
12	60.37	7946.0	80	33.71	7881	0	7897	3	0	0	0.00	232	21.61	746	77.99	0	0.00	43	10.39	0	0.00	11.00	41	0	17240	62220	0
12	60.39	7942.0	80	9.77	7718	0	7718	2	0	0	0.00	240	22.62	732	76.96	0	0.00	39	9.42	0	0.00	10.31	31	0	18040	61380	0
12	60.67	7950.0	80	10.41	7798	0	7798	0	0	0	0.00	240	22.32	738	77.58	0	0.00	40	9.66	0	0.00	9.92	38	0	17760	61740	0
12	60.37	7952.0	80	23.21	7737	0	7737	1	0	0	0.00	258	23.50	722	76.22	0	0.00	37	8.94	0	0.00	9.04	30	0	18740	60780	0
12	60.65	7950.0	80	16.07	7642	0	7642	0	0	0	0.00	238	22.42	736	77.28	0	0.00	36	8.70	0	0.00	8.42	34	0	17880	61620	0
12	60.93	7954.0	80	58.81	6619	0	6619	2	0	0	0.00	248	22.94	730	76.86	0	0.00	41	9.90	0	0.00	11.27	43	0	18280	61260	0
12	60.78	7942.0	80	49.03	7712	0	7712	2	0	0	0.00	232	22.20	738	77.52	0	0.00	41	9.90	0	0.00	8.88	44	0	17680	61740	0
12	60.56	7928.0	80	24.74	7729	0	7729	1	0	0	0.00	234	22.43	732	76.92	0	0.00	32	7.73	0	0.00	9.92	36	0	17900	61380	0
12	60.78	7956.0	80	51.25	7758	0	7758	4	0	0	0.00	246	23.60	722	76.38	0	0.00	33	7.97	0	0.00	9.65	32	0	18780	60780	0
12	60.79	7928.0	80	36.43	7547	0	7547	1	0	0	0.00	222	21.42	746	78.13	0	0.00	38	9.18	0	0.00	10.31	45	0	17060	62220	0
36	77.66	7948.0	80	32.07	9848	0	9848	3	0	0	0.00	220	21.23	752	78.60	0	0.00	39	9.42	0	0.00	9.15	40	0	16900	62580	0
36	74.43	7926.0	80	50.65	9296	0	9296	3	0	0	0.00	232	21.92	738	77.25	0	0.00	32	7.73	0	0.00	10.35	42	0	17520	61740	0
36	66.52	7932.0	80	28.95	8679	0	8679	3	0	0	0.00	234	22.01	740	77.99	0	0.00	31	7.49	0	0.00	9.58	36	0	17460	61860	0
36	74.94	7946.0	80	57.27	9929	0	9708	2	0	0	0.00	244	22.62	732	76.80	0	0.00	29	7.00	0	0.00	11.50	41	0	18080	61380	0
36	71.45	7948.0	80	56.82	9245	0	9245	0	0	0	0.00	240	22.55	734	77.13	0	0.00	38	9.18	0	0.00	10.23	39	0	17980	61500	0
36	70.81	7944.0	80	41.86	9205	0	9205	6	0	0	0.00	232	21.86	742	77.61	0	0.00	31	7.49	0	0.00	10.42	41	0	17460	61980	0
36	72.79	7942.0	80	4.09	9377	0	9377	0	0	0	0.00	218	21.35	750	78.65	0	0.00	37	8.94	0	0.00	8.42	32	0	16960	62460	0
36	72.96	7956.0	80	48.27	8621	0	8621	2	0	0	0.00	240	23.15	728	76.85	0	0.00	36	8.70	0	0.00	10.69	39	0	18420	61140	0
36	67.58	7941.6	80	8.67	8796	0	8796	1	0	0	0.00	230	22.14	738	77.74	1	0.12	38	9.18	0	0.00	10.31	47	0	17580	61740	96
36	70.86	7956.0	80	0.19	9310	0	9310	2	0	0	0.00	236	23.22	726	76.43	0	0.00	40	9.66	0	0.00	11.19	42	0	18540	61020	0
36*	61.12	7956.0	80	42.73	7932	0	7932	3	0	0	0.00	236	22.55	736	77.45	0	0.00	35	8.45	0	0.00	8.35	40	0	17940	61620	0
36*	61.43	7932.0	80	23.35	8005	0	8005	2	0	0	0.00	234	22.01	740	77.99	0	0.00	31	7.49	0	0.00	9.58	36	0	17460	61860	0
36*	74.77	7946.0	80	56.15	9724	0	9724	6	0	0	0.00	234	22.45	736	77.55	0	0.00	30	7.25	0	0.00	11.15	40	0	17840	61620	0
36*	61.35	7942.0	80	46.75	8032	0	8032	3	0	0	0.00	228	21.66	746	78.34	0	0.00	40	9.66	0	0.00	7.81	32	0	17200	62220	0
36*	61.31	7948.0	80	49.17	7955	0	7955	2	0	0	0.00	244	23.23	726	76.77	0	0.00	34	8.21	0	0.00	8.42	26	0	18460	61020	0
36*	61.51	7948.0	80	53.57	8001	0	8001	1	0	0	0.00	240	22.62	734	77.38	0	0.00	38	9.18	0	0.00	10.23	39	0	17980	61500	0
36*	61.26	7938.0	80	52.21	7628	0	7628	3	0	0	0.00	238	22.52	734	77.48	0	0.00	38	9.18	0	0.00	11.58	43	0	17880	61500	0
36*	61.23	7924.0	80	32.31	7850	0	7850	4	0	0	0.00	228	21.78	742	78.22	0	0.00	42	10.14	0	0.00	11.88	44	0	17260	61980	0
36*	61.62	7944.0	80	42.98	8052	0	8052	1	0	0	0.00	244	23.04	728	76.96	0	0.00	34	8.21	0	0.00	10.27	39	0	18300	61140	0
36*	61.14	7946.0	80	30.95	7688	0	7688	1	0	0	0.00	240	22.90	730	77.10	0	0.00	40	9.66	0	0.00	7.46	33	0	18200	61260	0

Table D.50: Results of all runs made with GBN network case 9, in 60 seconds.

D.6 GBN, Given 300 Seconds

Symbol	Name
$\#T$	Number of Threads
t_E	Time of Execution
C	Best Cost Solution found
CA	Highest Channel Assigned
t_{sol}	Found Solution Time
$\#i$	Number of Iterations
$\#IS$	Number of Invalid Solutions
$\#G_U$	Number of Greedy Solutions Unfeasible
$\#LS_U$	Number of Local Search Solutions Unfeasible
UD	Unfeasible Degree
$\#IM$	Number of Invert Multiplex used
C_{IM}	Cost % of Invert Multiplex
$\#MX$	Number of Muxponders placed
C_{MX}	Cost % of Muxponders
$\#TX$	Number of Transponders placed
C_{TX}	Cost % of Transponders
$\#3R$	Number of $3R$ regenerators placed
C_{3R}	Cost % of $3R$ regenerators
#10	Number of Multi-Hop Grooming of $10Gb/s$
%10	Traffic % of Multi-Hop Grooming of $10Gb/s$
#40	Number of Multi-hop Grooming of $40Gb/s$
%40	Traffic % of Multi-hop Grooming of $40Gb/s$
$\bar{m}F$	Average Fragmentation at Channel Assigned
MF	Max Fragmentation at Channel Assigned
C_{IM}	Cost of Invert Multiplexers
C_{MX}	Cost of Multiplexers
C_{TX}	Cost of Transponders
C_{3R}	Cost of $3R$ regenerators

Table D.51: Header symbols and their description.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.19	4730.0	58	102.68	46912	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	12	1.33	0	0.00	11.00	30	0	23300	24000	0
1	300.33	4730.0	60	107.36	46831	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	12	1.33	0	0.00	12.04	38	0	23300	24000	0
1	300.19	4730.0	59	276.04	46801	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	9	1.00	0	0.00	13.62	38	0	23300	24000	0
1	300.33	4730.0	57	188.84	46883	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	9	1.00	0	0.00	12.62	30	0	23300	24000	0
1	300.19	4730.0	64	62.54	46861	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	13	1.44	0	0.00	13.23	33	0	23300	24000	0
1	300.19	4730.0	57	184.77	46850	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	13	1.44	0	0.00	10.54	25	0	23300	24000	0
1	300.32	4736.0	56	239.51	46837	0	0	0	0	0	0.00	464	49.32	280	50.68	0	0.00	8	0.89	0	0.00	11.88	23	0	23360	24000	0
1	300.19	4730.0	63	204.09	47044	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	8	0.89	0	0.00	15.08	28	0	23300	24000	0
1	300.33	4736.0	57	70.53	46837	0	0	0	0	0	0.00	464	49.32	280	50.68	0	0.00	9	1.00	0	0.00	9.27	29	0	23360	24000	0
1	300.19	4730.0	63	173.53	46858	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	9	1.00	0	0.00	13.08	35	0	23300	24000	0
12	300.22	4730.0	58	41.12	448272	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	10	1.11	0	0.00	10.19	36	0	23300	24000	0
12	300.21	4730.0	56	153.52	464747	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	11	1.22	0	0.00	11.96	31	0	23300	24000	0
12	300.35	4730.0	59	291.25	451051	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	11	1.22	0	0.00	10.92	29	0	23300	24000	0
12	300.21	4730.0	57	43.27	447065	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	9	1.00	0	0.00	10.69	28	0	23300	24000	0
12	300.33	4730.0	56	73.77	447898	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	10	1.11	0	0.00	11.35	34	0	23300	24000	0
12	300.21	4730.0	56	144.97	458163	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	10	1.11	0	0.00	9.96	20	0	23300	24000	0
12	301.16	4730.0	58	88.02	461807	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	10	1.11	0	0.00	14.92	31	0	23300	24000	0
12	300.39	4730.0	57	50.19	454238	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	13	1.44	0	0.00	10.77	19	0	23300	24000	0
12	300.28	4730.0	58	22.70	465958	0	0	0	0	0	0.00	466	49.20	280	50.68	0	0.00	9	1.00	0	0.00	11.35	28	0	23300	24000	0
12	300.36	4730.0	57	204.77	477889	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	13	1.44	0	0.00	10.54	25	0	23300	24000	0
36	313.37	4730.0	56	52.57	512110	0	0	0	0	0	0.00	466	49.20	280	50.68	0	0.00	10	1.11	0	0.00	9.96	20	0	23300	24000	0
36	313.73	4726.0	56	145.33	504218	0	0	0	0	0	0.00	462	49.11	280	50.68	0	0.00	12	1.33	0	0.00	12.19	30	0	23260	24000	0
36	307.41	4726.0	58	252.75	497606	0	0	0	0	0	0.00	462	49.15	280	50.72	0	0.00	12	1.33	0	0.00	8.65	30	0	23260	24000	0
36	314.11	4730.0	57	84.33	504525	0	0	0	0	0	0.00	466	49.20	280	50.68	0	0.00	8	0.89	0	0.00	11.15	32	0	23300	24000	0
36	314.06	4730.0	57	105.49	515518	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	8	0.89	0	0.00	10.58	23	0	23300	24000	0
36	307.44	4730.0	57	218.09	508153	0	0	0	0	0	0.00	466	49.20	280	50.68	0	0.00	10	1.11	0	0.00	10.27	35	0	23300	24000	0
36	312.41	4730.0	56	150.71	508572	0	0	0	0	0	0.00	466	49.20	280	50.68	0	0.00	10	1.11	0	0.00	9.96	20	0	23300	24000	0
36	315.01	4730.0	57	81.89	518743	0	0	0	0	0	0.00	466	49.20	280	50.68	0	0.00	10	1.11	0	0.00	10.42	26	0	23300	24000	0
36	312.23	4730.0	57	105.64	507314	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	9	1.00	0	0.00	11.77	32	0	23300	24000	0
36	311.49	4730.0	57	106.88	519004	0	0	0	0	0	0.00	466	49.20	280	50.68	0	0.00	10	1.11	0	0.00	12.81	39	0	23300	24000	0
36*	313.19	4730.0	56	84.72	486458	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	9	1.00	0	0.00	10.96	26	0	23300	24000	0
36*	307.87	4730.0	58	127.00	494545	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	9	1.00	0	0.00	11.92	24	0	23300	24000	0
36*	301.10	4730.0	57	171.49	477921	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	11	1.22	0	0.00	12.77	28	0	23300	24000	0
36*	314.75	4730.0	57	43.98	497851	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	10	1.11	0	0.00	10.54	23	0	23300	24000	0
36*	307.43	4730.0	56	160.59	495745	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	9	1.00	0	0.00	12.27	29	0	23300	24000	0
36*	313.86	4730.0	58	254.08	481808	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	11	1.22	0	0.00	13.62	35	0	23300	24000	0
36*	313.54	4730.0	57	98.84	509853	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	10	1.11	0	0.00	10.42	26	0	23300	24000	0
36*	307.43	4730.0	57	104.40	490390	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	9	1.00	0	0.00	11.77	32	0	23300	24000	0
36*	301.06	4730.0	56	250.57	495101	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	10	1.11	0	0.00	9.96	20	0	23300	24000	0
36*	313.89	4730.0	56	46.25	493418	0	0	0	0	0	0.00	466	49.26	280	50.74	0	0.00	9	1.00	0	0.00	10.12	24	0	23300	24000	0

Table D.52: Results of all runs made with GBN network case 1, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.36	5178.0	73	8.33	49838	0	1758	138	0	0	0.00	212	22.94	530	77.06	0	0.00	9	2.00	0	0.00	15.96	31	0	11880	39900	0
1	300.35	5178.0	73	33.75	51784	0	1876	132	0	0	0.00	212	22.94	530	77.06	0	0.00	7	1.56	0	0.00	16.62	49	0	11880	39900	0
1	300.19	5178.0	74	116.38	51992	0	1855	136	0	0	0.00	212	22.94	530	77.06	0	0.00	7	1.56	0	0.00	16.42	35	0	11880	39900	0
1	300.21	5178.0	72	128.90	51898	0	1856	140	0	0	0.00	212	22.94	530	77.06	0	0.00	9	2.00	0	0.00	15.96	31	0	11880	39900	0
1	300.35	5178.0	72	114.69	52019	0	1721	110	0	0	0.00	212	22.94	530	77.06	0	0.00	9	2.00	0	0.00	17.38	37	0	11880	39900	0
1	300.21	5178.0	72	78.56	52321	0	1796	132	0	0	0.00	212	22.94	530	77.06	0	0.00	11	2.44	0	0.00	15.42	36	0	11880	39900	0
1	300.35	5178.0	73	162.85	52191	0	1759	139	0	0	0.00	212	22.94	530	77.06	0	0.00	8	1.78	0	0.00	15.35	38	0	11880	39900	0
1	300.21	5178.0	73	10.41	51949	0	1760	130	0	0	0.00	212	22.94	530	77.06	0	0.00	9	2.00	0	0.00	15.46	30	0	11880	39900	0
1	300.35	5178.0	73	4.62	52237	0	1904	131	0	0	0.00	212	22.94	530	77.06	0	0.00	9	2.00	0	0.00	13.38	31	0	11880	39900	0
1	300.35	5178.0	73	156.39	52100	0	1798	133	0	0	0.00	212	22.94	530	77.06	0	0.00	7	1.56	0	0.00	15.65	30	0	11880	39900	0
12	300.36	5178.0	72	52.14	427673	0	14793	1037	0	0	0.00	212	22.94	530	77.06	0	0.00	9	2.00	0	0.00	13.85	28	0	11880	39900	0
12	300.21	5178.0	72	92.13	458008	66	15821	1175	0	0	0.00	212	22.94	530	77.06	0	0.00	10	2.22	0	0.00	14.69	28	0	11880	39900	0
12	300.38	5176.0	76	245.72	446497	0	15338	1102	0	0	0.00	202	22.90	530	77.06	0	0.00	8	1.78	0	0.00	15.38	33	0	11860	39900	0
12	300.21	5176.0	73	183.77	443855	0	15137	1061	0	0	0.00	202	22.90	530	77.06	0	0.00	8	1.78	0	0.00	15.88	37	0	11860	39900	0
12	300.38	5176.0	72	25.90	434887	0	15164	1091	0	0	0.00	202	22.90	530	77.06	0	0.00	8	1.78	0	0.00	16.62	35	0	11860	39900	0
12	300.36	5178.0	72	8.50	489740	0	16967	1197	0	0	0.00	212	22.94	530	77.06	0	0.00	10	2.22	0	0.00	19.35	43	0	11880	39900	0
12	300.22	5178.0	72	8.58	418075	0	14514	995	0	0	0.00	212	22.94	530	77.06	0	0.00	11	2.44	0	0.00	14.65	28	0	11880	39900	0
12	300.38	5174.0	73	264.42	504188	0	17702	1285	0	0	0.00	208	22.87	530	77.06	0	0.00	8	1.78	0	0.00	16.92	40	0	11840	39900	0
12	300.21	5178.0	72	100.53	453330	0	15903	1110	0	0	0.00	212	22.94	530	77.06	0	0.00	7	1.56	0	0.00	16.00	45	0	11880	39900	0
12	300.21	5176.0	78	290.85	471017	0	16470	1139	0	0	0.00	202	22.90	530	77.06	0	0.00	8	1.78	0	0.00	16.35	49	0	11860	39900	0
36	316.57	5176.0	73	294.11	517824	0	18229	1281	0	0	0.00	202	22.90	530	77.06	0	0.00	7	1.56	0	0.00	19.46	36	0	11860	39900	0
36	306.57	5176.0	76	261.80	482991	0	16850	1182	0	0	0.00	202	22.90	530	77.06	0	0.00	9	2.00	0	0.00	17.58	50	0	11860	39900	0
36	316.20	5174.0	76	209.65	486238	0	17008	1225	0	0	0.00	208	22.87	530	77.06	0	0.00	9	2.00	0	0.00	16.58	41	0	11840	39900	0
36	314.22	5176.0	73	93.02	493620	0	17238	1239	0	0	0.00	202	22.90	530	77.06	0	0.00	8	1.78	0	0.00	15.96	33	0	11860	39900	0
36	313.72	5176.0	76	217.14	483303	0	16745	1217	0	0	0.00	202	22.90	530	77.06	0	0.00	8	1.78	0	0.00	15.38	33	0	11860	39900	0
36	310.94	5178.0	72	11.86	497464	0	17473	1158	0	0	0.00	212	22.94	530	77.06	0	0.00	9	2.00	0	0.00	14.38	29	0	11880	39900	0
36	316.48	5176.0	73	37.19	493732	0	17187	1224	0	0	0.00	202	22.90	530	77.03	0	0.00	7	1.56	0	0.00	17.73	45	0	11860	39900	0
36	308.41	5178.0	72	12.86	484055	0	17048	1202	0	0	0.00	212	22.94	530	77.06	0	0.00	9	2.00	0	0.00	13.31	35	0	11880	39900	0
36	307.15	5178.0	72	78.42	491629	0	17109	1226	0	0	0.00	212	22.94	530	77.06	0	0.00	10	2.22	0	0.00	16.81	38	0	11880	39900	0
36	314.15	5178.0	72	3.84	488686	0	17011	1191	0	0	0.00	212	22.94	530	77.06	0	0.00	7	1.56	0	0.00	15.69	33	0	11880	39900	0
36*	301.11	5178.0	72	109.82	454711	0	15999	1165	0	0	0.00	212	22.94	530	77.06	0	0.00	10	2.22	0	0.00	13.42	24	0	11880	39900	0
36*	310.02	5178.0	72	19.67	492729	0	17152	1160	0	0	0.00	212	22.94	530	77.06	0	0.00	9	2.00	0	0.00	18.04	36	0	11880	39900	0
36*	314.48	5176.0	73	94.49	465815	0	16223	1145	0	0	0.00	202	22.91	530	77.09	0	0.00	8	1.78	0	0.00	15.96	33	0	11860	39900	0
36*	301.20	5176.0	76	56.07	463378	0	16030	1115	0	0	0.00	202	22.91	530	77.09	0	0.00	8	1.78	0	0.00	14.92	38	0	11860	39900	0
36*	306.29	5176.0	72	112.83	429245	0	14876	1062	0	0	0.00	202	22.91	530	77.09	0	0.00	8	1.78	0	0.00	15.15	38	0	11860	39900	0
36*	300.97	5176.0	75	19.84	454716	0	15608	1106	0	0	0.00	202	22.91	530	77.09	0	0.00	8	1.78	0	0.00	15.69	34	0	11860	39900	0
36*	310.19	5174.0	76	97.38	523424	0	18273	1286	0	0	0.00	208	22.88	530	77.12	0	0.00	7	1.56	0	0.00	12.50	30	0	11840	39900	0
36*	314.36	5176.0	79	214.89	500907	0	17714	1248	0	0	0.00	202	22.91	530	77.09	0	0.00	8	1.78	0	0.00	16.85	41	0	11860	39900	0
36*	315.45	5178.0	72	54.83	487705	0	16918	1196	0	0	0.00	212	22.94	530	77.06	0	0.00	7	1.56	0	0.00	15.96	41	0	11880	39900	0
36*	306.77	5178.0	72	53.90	450433	0	15869	1120	0	0	0.00	212	22.94	530	77.06	0	0.00	10	2.22	0	0.00	16.92	45	0	11880	39900	0

Table D.53: Results of all runs made with GBN network case 2, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.19	5570.0	59	184.14	46093	0	0	0	0	0	0.00	150	14.90	580	85.10	0	0.00	15	5.00	0	0.00	14.77	33	0	8300	47400	0
1	300.35	5566.0	58	254.56	46450	0	0	0	0	0	0.00	146	14.84	580	85.16	0	0.00	15	5.00	0	0.00	13.50	41	0	8260	47400	0
1	300.19	5566.0	61	76.99	46059	0	0	0	0	0	0.00	146	14.84	580	85.16	0	0.00	14	4.67	0	0.00	17.69	37	0	8260	47400	0
1	300.35	5570.0	59	287.85	46650	0	0	0	0	0	0.00	150	14.90	580	85.10	0	0.00	14	4.67	0	0.00	13.19	29	0	8300	47400	0
1	300.35	5570.0	60	18.63	46183	0	0	0	0	0	0.00	150	14.90	580	85.10	0	0.00	14	4.67	0	0.00	12.96	35	0	8300	47400	0
1	300.19	5570.0	57	167.19	46095	0	0	0	0	0	0.00	150	14.90	580	85.10	0	0.00	12	4.00	0	0.00	11.23	23	0	8300	47400	0
1	300.35	5570.0	58	190.74	46208	0	0	0	0	0	0.00	150	14.90	580	85.10	0	0.00	15	5.00	0	0.00	9.73	26	0	8300	47400	0
1	300.36	5570.0	55	219.07	46583	0	0	0	0	0	0.00	150	14.90	580	85.10	0	0.00	13	4.33	0	0.00	11.85	25	0	8300	47400	0
1	300.19	5570.0	61	25.90	45947	0	0	0	0	0	0.00	150	14.90	580	85.10	0	0.00	12	4.00	0	0.00	12.73	39	0	8300	47400	0
1	300.36	5570.0	59	131.68	46082	0	0	0	0	0	0.00	150	14.90	580	85.10	0	0.00	12	4.00	0	0.00	14.46	56	0	8300	47400	0
12	300.22	5566.0	62	22.62	425681	0	0	0	0	0	0.00	146	14.83	580	85.10	0	0.00	11	3.67	0	0.00	14.04	32	0	8260	47400	0
12	300.36	5570.0	57	122.93	432093	0	0	0	0	0	0.00	150	14.90	580	85.10	0	0.00	13	4.33	0	0.00	10.15	37	0	8300	47400	0
12	300.21	5566.0	57	50.68	446128	0	0	0	0	0	0.00	146	14.83	580	85.10	0	0.00	12	4.00	0	0.00	13.42	42	0	8260	47400	0
12	300.38	5566.0	59	112.99	464283	0	0	0	0	0	0.00	146	14.82	580	85.04	0	0.00	12	4.00	0	0.00	14.12	36	0	8260	47400	0
12	300.21	5566.0	57	82.31	422126	0	0	0	0	0	0.00	146	14.83	580	85.10	0	0.00	13	4.33	0	0.00	9.77	37	0	8260	47400	0
12	300.38	5566.0	60	176.59	443691	0	0	0	0	0	0.00	146	14.83	580	85.10	0	0.00	13	4.33	0	0.00	13.00	38	0	8260	47400	0
12	300.21	5566.0	58	133.29	431789	0	0	0	0	0	0.00	146	14.83	580	85.10	0	0.00	15	5.00	0	0.00	13.42	33	0	8260	47400	0
12	300.36	5566.0	58	277.60	432820	0	0	0	0	0	0.00	146	14.83	580	85.10	0	0.00	14	4.67	0	0.00	9.81	31	0	8260	47400	0
12	300.36	5566.0	59	147.39	457801	0	0	0	0	0	0.00	146	14.84	580	85.16	0	0.00	13	4.33	0	0.00	13.62	31	0	8260	47400	0
12	300.21	5566.0	58	55.82	432939	0	0	0	0	0	0.00	146	14.83	580	85.10	0	0.00	13	4.33	0	0.00	12.58	27	0	8260	47400	0
36	308.27	5566.0	58	163.52	499213	0	0	0	0	0	0.00	146	14.81	580	85.01	0	0.00	13	4.33	0	0.00	9.46	27	0	8260	47400	0
36	316.01	5566.0	56	112.62	502920	0	0	0	0	0	0.00	146	14.82	580	85.04	0	0.00	13	4.33	0	0.00	11.31	24	0	8260	47400	0
36	313.11	5566.0	62	214.06	498166	0	0	0	0	0	0.00	146	14.82	580	85.04	0	0.00	13	4.33	0	0.00	14.69	30	0	8260	47400	0
36	306.40	5566.0	59	74.71	502280	0	0	0	0	0	0.00	146	14.83	580	85.10	0	0.00	13	4.33	0	0.00	12.85	26	0	8260	47400	0
36	306.45	5566.0	57	172.12	487223	0	0	0	0	0	0.00	146	14.83	580	85.10	0	0.00	12	4.00	0	0.00	13.42	42	0	8260	47400	0
36	308.12	5566.0	58	36.58	495406	0	0	0	0	0	0.00	146	14.81	580	85.01	0	0.00	13	4.33	0	0.00	13.46	39	0	8260	47400	0
36	316.93	5566.0	57	2.62	501720	0	0	0	0	0	0.00	146	14.82	580	85.04	0	0.00	16	5.33	0	0.00	12.00	35	0	8260	47400	0
36	306.02	5566.0	55	178.12	493897	0	0	0	0	0	0.00	146	14.83	580	85.10	0	0.00	11	3.67	0	0.00	10.69	23	0	8260	47400	0
36	311.92	5566.0	62	181.15	493934	0	0	0	0	0	0.00	146	14.81	580	85.01	0	0.00	12	4.00	0	0.00	15.23	29	0	8260	47400	0
36	314.55	5566.0	57	40.73	502447	0	0	0	0	0	0.00	146	14.82	580	85.04	0	0.00	13	4.33	0	0.00	11.65	30	0	8260	47400	0
36*	308.74	5566.0	57	93.79	484729	0	0	0	0	0	0.00	146	14.84	580	85.16	0	0.00	12	4.00	0	0.00	13.27	37	0	8260	47400	0
36*	308.36	5566.0	59	39.23	482481	0	0	0	0	0	0.00	146	14.84	580	85.16	0	0.00	13	4.33	0	0.00	12.19	27	0	8260	47400	0
36*	314.54	5566.0	57	170.74	509897	0	0	0	0	0	0.00	146	14.84	580	85.16	0	0.00	12	4.00	0	0.00	9.88	29	0	8260	47400	0
36*	324.67	5566.0	62	48.34	511156	0	0	0	0	0	0.00	146	14.84	580	85.16	0	0.00	11	3.67	0	0.00	14.04	32	0	8260	47400	0
36*	309.22	5566.0	57	188.82	492290	0	0	0	0	0	0.00	146	14.84	580	85.16	0	0.00	12	4.00	0	0.00	13.42	42	0	8260	47400	0
36*	313.44	5566.0	57	290.25	456411	0	0	0	0	0	0.00	146	14.84	580	85.16	0	0.00	13	4.33	0	0.00	9.77	37	0	8260	47400	0
36*	313.50	5566.0	63	44.29	477793	0	0	0	0	0	0.00	146	14.84	580	85.16	0	0.00	13	4.33	0	0.00	17.08	42	0	8260	47400	0
36*	301.17	5566.0	58	117.45	468276	0	0	0	0	0	0.00	146	14.84	580	85.16	0	0.00	12	4.00	0	0.00	11.04	34	0	8260	47400	0
36*	307.76	5566.0	62	175.83	483785	0	0	0	0	0	0.00	146	14.84	580	85.16	0	0.00	12	4.00	0	0.00	15.23	29	0	8260	47400	0
36*	313.12	5566.0	59	138.50	462239	0	0	0	0	0	0.00	146	14.84	580	85.16	0	0.00	12	4.00	0	0.00	11.50	26	0	8260	47400	0

Table D.54: Results of all runs made with GBN network case 3, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.44	5692.0	76	204.74	20060	0	9087	1266	0	0	0.00	540	49.40	336	50.60	0	0.00	21	1.94	0	0.00	13.50	29	0	28120	28800	0
1	300.44	5688.0	79	154.63	20187	0	9011	1321	0	0	0.00	552	49.37	336	50.63	0	0.00	20	1.85	0	0.00	12.19	29	0	28080	28800	0
1	300.24	5690.0	78	122.19	20215	0	8988	1315	0	0	0.00	546	49.38	336	50.62	0	0.00	23	2.13	0	0.00	11.62	29	0	28100	28800	0
1	300.44	5688.0	80	274.14	20183	0	8995	1280	0	0	0.00	552	49.37	336	50.63	0	0.00	22	2.04	0	0.00	12.27	37	0	28080	28800	0
1	300.24	5688.0	78	63.07	20174	0	9019	1305	0	0	0.00	536	49.37	336	50.63	0	0.00	19	1.76	0	0.00	13.50	38	0	28080	28800	0
1	300.24	5690.0	77	92.52	20079	0	8963	1309	0	0	0.00	546	49.38	336	50.62	0	0.00	18	1.67	0	0.00	13.27	27	0	28100	28800	0
1	300.42	5692.0	80	108.78	20222	0	8920	1302	0	0	0.00	556	49.40	336	50.60	0	0.00	26	2.41	0	0.00	12.65	33	0	28120	28800	0
1	300.24	5690.0	80	132.58	20115	0	8891	1213	0	0	0.00	546	49.38	336	50.62	0	0.00	20	1.85	0	0.00	12.27	35	0	28100	28800	0
1	300.44	5686.0	77	58.84	20203	0	9019	1317	0	0	0.00	542	49.35	336	50.65	0	0.00	22	2.04	0	0.00	10.38	25	0	28060	28800	0
1	300.24	5686.0	80	104.13	20164	0	8909	1296	0	0	0.00	542	49.35	336	50.65	0	0.00	19	1.76	0	0.00	11.31	36	0	28060	28800	0
12	300.25	5686.0	80	289.01	196642	0	87791	12729	0	0	0.00	542	49.31	336	50.62	0	0.00	21	1.94	0	0.00	12.54	34	0	28060	28800	0
12	300.46	5686.0	79	298.40	197366	0	88092	12586	0	0	0.00	542	49.31	336	50.62	0	0.00	16	1.48	0	0.00	12.58	24	0	28060	28800	0
12	300.44	5680.0	77	89.33	199888	0	89432	12639	0	0	0.00	544	49.21	336	50.62	0	0.00	17	1.57	0	0.00	13.54	31	0	28000	28800	0
12	300.25	5684.0	80	80.65	180562	0	80359	11381	0	0	0.00	548	49.30	336	50.63	0	0.00	18	1.67	0	0.00	10.58	42	0	28040	28800	0
12	300.46	5688.0	78	276.65	201731	0	89968	12913	0	0	0.00	552	49.37	336	50.63	0	0.00	18	1.67	0	0.00	13.73	34	0	28080	28800	0
12	300.27	5688.0	80	100.99	197017	0	87892	12503	0	0	0.00	552	49.35	336	50.62	0	0.00	18	1.67	0	0.00	11.92	34	0	28080	28800	0
12	300.42	5686.0	77	115.67	203954	0	91536	13175	0	0	0.00	542	49.30	336	50.60	0	0.00	18	1.67	0	0.00	13.46	34	0	28060	28800	0
12	300.47	5682.0	80	298.73	200498	0	89502	12674	0	0	0.00	554	49.21	336	50.58	0	0.00	23	2.13	0	0.00	14.04	42	0	28020	28800	0
12	300.27	5684.0	78	233.03	191107	0	85352	12309	0	0	0.00	548	49.24	336	50.58	0	0.00	20	1.85	0	0.00	11.65	27	0	28040	28800	0
12	300.44	5684.0	78	83.74	196820	0	88170	12469	0	0	0.00	548	49.28	336	50.62	0	0.00	18	1.67	0	0.00	13.19	36	0	28040	28800	0
36	315.01	5686.0	77	164.78	201881	0	90173	12832	0	0	0.00	542	49.28	336	50.58	0	0.00	17	1.57	0	0.00	10.96	26	0	28060	28800	0
36	314.54	5686.0	78	173.80	207013	0	92281	13106	0	0	0.00	542	49.28	336	50.58	0	0.00	19	1.76	0	0.00	14.08	36	0	28060	28800	0
36	311.78	5684.0	78	221.57	211243	0	94322	13378	0	0	0.00	548	49.24	336	50.58	0	0.00	23	2.13	0	0.00	13.65	34	0	28040	28800	0
36	314.59	5686.0	77	99.86	196810	0	88169	12793	0	0	0.00	542	49.28	336	50.58	0	0.00	23	2.13	0	0.00	12.23	25	0	28060	28800	0
36	312.56	5686.0	80	277.51	205940	0	92119	12907	0	0	0.00	542	49.28	336	50.58	0	0.00	23	2.13	0	0.00	12.58	28	0	28060	28800	0
36	309.39	5688.0	79	137.84	207600	0	92672	13220	0	0	0.00	552	49.33	336	50.60	0	0.00	20	1.85	0	0.00	13.04	30	0	28080	28800	0
36	316.37	5684.0	77	289.74	207872	0	93043	13271	0	0	0.00	548	49.21	336	50.54	0	0.00	18	1.67	0	0.00	12.50	27	0	28040	28800	0
36	308.58	5684.0	78	73.01	219322	0	98292	14300	0	0	0.00	548	49.24	336	50.58	0	0.00	19	1.76	0	0.00	11.77	26	0	28040	28800	0
36	309.54	5682.0	79	156.41	205291	0	91537	13061	0	0	0.00	538	49.19	336	50.56	0	0.00	18	1.67	0	0.00	13.23	37	0	28020	28800	0
36	314.62	5684.0	78	77.06	200148	0	89317	12609	0	0	0.00	548	49.21	336	50.54	0	0.00	18	1.67	0	0.00	13.19	36	0	28040	28800	0
36*	313.76	5684.0	77	18.78	212292	0	94820	13476	0	0	0.00	548	49.33	336	50.67	0	0.00	17	1.57	0	0.00	12.65	37	0	28040	28800	0
36*	300.92	5686.0	79	66.24	199690	0	88850	12610	0	0	0.00	542	49.35	336	50.65	0	0.00	20	1.85	0	0.00	13.04	39	0	28060	28800	0
36*	309.54	5684.0	79	139.54	204120	0	91568	13164	0	0	0.00	548	49.33	336	50.67	0	0.00	20	1.85	0	0.00	12.58	33	0	28040	28800	0
36*	306.95	5688.0	78	118.75	205486	0	91671	13078	0	0	0.00	552	49.37	336	50.63	0	0.00	21	1.94	0	0.00	12.77	29	0	28080	28800	0
36*	315.54	5686.0	76	7.18	206968	0	92272	13135	0	0	0.00	542	49.35	336	50.65	0	0.00	22	2.04	0	0.00	14.88	36	0	28060	28800	0
36*	313.84	5686.0	78	186.12	203526	0	90758	13070	0	0	0.00	542	49.35	336	50.65	0	0.00	19	1.76	0	0.00	12.92	36	0	28060	28800	0
36*	306.52	5686.0	78	171.96	210162	0	93945	13366	0	0	0.00	542	49.35	336	50.65	0	0.00	20	1.85	0	0.00	10.81	26	0	28060	28800	0
36*	313.83	5686.0	77	221.61	199769	0	89089	12616	0	0	0.00	542	49.35	336	50.65	0	0.00	20	1.85	0	0.00	12.88	31	0	28060	28800	0
36*	301.03	5684.0	78	39.27	197801	0	87943	12616	0	0	0.00	548	49.33	336	50.67	0	0.00	20	1.85	0	0.00	12.46	36	0	28040	28800	0
36*	301.00	5686.0	77	122.71	193226	0	86109	12386	0	0	0.00	542	49.35	336	50.65	0	0.00	17	1.57	0	0.00	12.96	32	0	28060	28800	0

Table D.55: Results of all runs made with GBN network case 4, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
#T	t_E	C	CA	t_{sol}	#i	#IS	#G_U	#LS_U	UD	#IM	C_{IM}	#MX	C_{MX}	#TX	C_{TX}	#3R	C_{3R}	#10G	%10G	#40G	%40G	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.24	6232.0	80	82.31	17180	0	14688	965	0	0	0.00	260	23.17	636	76.83	0	0.00	15	2.78	0	0.00	11.73	32	0	14440	47880	0
1	300.25	6230.0	78	137.87	17055	0	14627	992	0	0	0.00	250	23.15	636	76.85	0	0.00	12	2.22	0	0.00	12.19	33	0	14420	47880	0
1	300.42	6232.0	79	141.87	17184	0	14682	1031	0	0	0.00	260	23.17	636	76.83	0	0.00	16	2.96	0	0.00	13.42	40	0	14440	47880	0
1	300.35	6232.0	78	77.55	17146	0	14727	1040	0	0	0.00	244	23.17	636	76.83	0	0.00	11	2.04	0	0.00	14.08	45	0	14440	47880	0
1	300.44	6228.0	78	180.35	17206	0	14711	975	0	0	0.00	256	23.12	636	76.88	0	0.00	16	2.96	0	0.00	12.00	37	0	14400	47880	0
1	300.24	6234.0	79	3.65	17119	0	14776	1042	0	0	0.00	254	23.20	636	76.80	0	0.00	18	3.33	0	0.00	11.77	36	0	14460	47880	0
1	300.44	6234.0	78	130.46	17178	0	14763	985	0	0	0.00	254	23.20	636	76.80	0	0.00	18	3.33	0	0.00	11.27	39	0	14460	47880	0
1	300.24	6230.0	78	122.09	17194	0	14763	1054	0	0	0.00	250	23.15	636	76.85	0	0.00	13	2.41	0	0.00	10.50	40	0	14420	47880	0
1	300.27	6230.0	77	26.07	17317	0	14880	1090	0	0	0.00	250	23.15	636	76.85	0	0.00	14	2.59	0	0.00	11.85	31	0	14420	47880	0
1	300.46	6234.0	78	60.98	17189	0	14694	985	0	0	0.00	254	23.20	636	76.80	0	0.00	12	2.22	0	0.00	11.12	33	0	14460	47880	0
12	300.47	6226.0	79	123.13	159145	0	136615	9418	0	0	0.00	262	23.07	636	76.83	0	0.00	15	2.78	0	0.00	11.46	43	0	14380	47880	0
12	300.27	6226.0	79	186.17	161949	0	138826	9589	0	0	0.00	262	23.07	636	76.80	0	0.00	13	2.41	0	0.00	12.04	48	0	14380	47880	0
12	300.47	6226.0	79	288.69	160006	0	137402	9657	0	0	0.00	262	23.07	636	76.80	0	0.00	14	2.59	0	0.00	10.23	30	0	14380	47880	0
12	300.47	6232.0	78	196.56	167564	0	143868	10037	0	0	0.00	260	23.17	636	76.83	0	0.00	15	2.78	0	0.00	11.85	32	0	14440	47880	0
12	300.27	6224.0	78	84.91	175880	0	151009	10387	0	0	0.00	252	23.04	636	76.80	0	0.00	14	2.59	0	0.00	12.38	36	0	14360	47880	0
12	300.46	6228.0	77	7.47	165480	0	142191	9902	0	0	0.00	256	23.11	636	76.85	0	0.00	12	2.22	0	0.00	11.96	39	0	14400	47880	0
12	300.28	6228.0	79	163.18	163068	0	140116	9733	0	0	0.00	256	23.09	636	76.78	0	0.00	16	2.96	0	0.00	11.81	39	0	14400	47880	0
12	300.44	6228.0	79	92.66	171132	0	146909	10205	0	0	0.00	256	23.11	636	76.83	0	0.00	17	3.15	0	0.00	11.04	42	0	14400	47880	0
12	300.46	6226.0	80	41.37	170413	0	146463	10201	0	0	0.00	262	23.06	636	76.78	0	0.00	16	2.96	0	0.00	13.12	45	0	14380	47880	0
12	300.28	6228.0	78	3.81	164432	0	141259	9885	0	0	0.00	256	23.09	636	76.78	0	0.00	17	3.15	0	0.00	10.65	29	0	14400	47880	0
36	314.25	6228.0	79	114.24	181231	0	155557	10735	0	0	0.00	256	23.08	636	76.76	0	0.00	16	2.96	0	0.00	11.38	36	0	14400	47880	0
36	314.64	6226.0	80	69.72	183875	0	157862	11066	0	0	0.00	262	23.04	636	76.73	0	0.00	14	2.59	0	0.00	10.77	36	0	14380	47880	0
36	311.95	6228.0	79	196.09	182715	0	156909	10931	0	0	0.00	256	23.08	636	76.73	0	0.00	13	2.41	0	0.00	11.12	33	0	14400	47880	0
36	315.32	6230.0	80	239.38	180748	0	155231	10805	0	0	0.00	250	23.12	636	76.76	0	0.00	15	2.78	0	0.00	11.73	38	0	14420	47880	0
36	317.88	6226.0	79	270.43	186805	0	160560	11171	0	0	0.00	262	23.05	636	76.76	0	0.00	14	2.59	0	0.00	10.23	30	0	14380	47880	0
36	314.59	6230.0	78	21.40	183130	0	157193	10765	0	0	0.00	250	23.12	636	76.76	0	0.00	16	2.96	0	0.00	11.12	41	0	14420	47880	0
36	309.69	6228.0	80	45.27	185330	0	159032	11081	0	0	0.00	256	23.09	636	76.78	0	0.00	14	2.59	0	0.00	12.08	34	0	14400	47880	0
36	311.98	6228.0	79	68.47	183709	0	157739	10933	0	0	0.00	256	23.08	636	76.76	0	0.00	15	2.78	0	0.00	11.35	35	0	14400	47880	0
36	316.63	6228.0	78	198.25	187026	0	160427	11282	0	0	0.00	256	23.08	636	76.76	0	0.00	15	2.78	0	0.00	12.04	37	0	14400	47880	0
36	317.65	6228.0	78	16.72	186866	0	160456	11118	0	0	0.00	256	23.09	636	76.78	0	0.00	17	3.15	0	0.00	10.65	29	0	14400	47880	0
36*	314.64	6228.0	78	168.25	178535	0	153240	10719	0	0	0.00	256	23.12	636	76.88	0	0.00	15	2.78	0	0.00	12.73	44	0	14400	47880	0
36*	313.48	6226.0	80	86.77	186253	0	159926	11043	0	0	0.00	262	23.10	636	76.90	0	0.00	14	2.59	0	0.00	10.77	36	0	14380	47880	0
36*	301.20	6228.0	79	108.94	166759	0	143064	9966	0	0	0.00	256	23.12	636	76.88	0	0.00	16	2.96	0	0.00	9.73	30	0	14400	47880	0
36*	300.85	6228.0	78	77.27	172788	0	148319	10230	0	0	0.00	256	23.12	636	76.88	0	0.00	15	2.78	0	0.00	13.19	42	0	14400	47880	0
36*	301.14	6224.0	79	195.70	178437	0	153079	10599	0	0	0.00	252	23.07	636	76.93	0	0.00	15	2.78	0	0.00	12.12	44	0	14360	47880	0
36*	300.88	6230.0	79	11.44	178234	0	153292	10698	0	0	0.00	250	23.15	636	76.85	0	0.00	15	2.78	0	0.00	10.38	34	0	14420	47880	0
36*	300.91	6228.0	79	241.75	162680	0	139827	9804	0	0	0.00	256	23.12	636	76.88	0	0.00	16	2.96	0	0.00	11.81	39	0	14400	47880	0
36*	307.04	6226.0	80	191.91	172422	0	148115	10419	0	0	0.00	262	23.10	636	76.90	0	0.00	16	2.96	0	0.00	13.12	45	0	14380	47880	0
36*	308.02	6226.0	79	165.69	173264	0	148636	10201	0	0	0.00	262	23.10	636	76.90	0	0.00	14	2.59	0	0.00	11.92	33	0	14380	47880	0
36*	301.02	6228.0	79	148.98	170711	0	146657	10175	0	0	0.00	256	23.12	636	76.88	0	0.00	16	2.96	0	0.00	11.38	36	0	14400	47880	0

Table D.56: Results of all runs made with GBN network case 5, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	#10G	%10G	#40G	%40G	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.25	6706.0	73	279.63	22274	0	172	0	0	0	0.00	194	15.18	696	84.82	0	0.00	24	6.67	0	0.00	13.23	24	0	10180	56880	0
1	300.46	6712.0	71	1.58	22324	0	177	0	0	0	0.00	192	15.26	696	84.74	0	0.00	24	6.67	0	0.00	12.31	25	0	10240	56880	0
1	300.27	6698.0	71	280.54	22266	0	195	0	0	0	0.00	186	15.08	696	84.92	0	0.00	19	5.28	0	0.00	12.15	28	0	10100	56880	0
1	300.25	6708.0	74	187.61	22239	0	178	0	0	0	0.00	188	15.21	696	84.79	0	0.00	22	6.11	0	0.00	13.08	32	0	10200	56880	0
1	300.46	6708.0	76	55.04	22311	0	161	0	0	0	0.00	188	15.21	696	84.79	0	0.00	19	5.28	0	0.00	12.00	29	0	10200	56880	0
1	300.25	6702.0	73	222.49	22217	0	180	0	0	0	0.00	190	15.13	696	84.87	0	0.00	20	5.56	0	0.00	10.42	25	0	10140	56880	0
1	300.49	6710.0	72	148.18	22249	0	186	0	0	0	0.00	198	15.23	696	84.77	0	0.00	22	6.11	0	0.00	11.46	29	0	10220	56880	0
1	300.24	6706.0	72	127.20	22235	0	189	0	0	0	0.00	194	15.18	696	84.82	0	0.00	17	4.72	0	0.00	12.58	30	0	10180	56880	0
1	300.46	6708.0	73	62.65	22247	0	176	0	0	0	0.00	188	15.21	696	84.79	0	0.00	22	6.11	0	0.00	12.85	29	0	10200	56880	0
1	300.25	6708.0	71	70.23	22305	0	175	0	0	0	0.00	188	15.21	696	84.79	0	0.00	20	5.56	0	0.00	13.85	29	0	10200	56880	0
12	300.36	6702.0	69	110.76	202642	0	1611	0	0	0	0.00	190	15.13	696	84.87	0	0.00	24	6.67	0	0.00	11.35	29	0	10140	56880	0
12	300.36	6698.0	71	292.34	229562	0	1884	0	0	0	0.00	186	15.06	696	84.79	0	0.00	22	6.11	0	0.00	13.27	30	0	10100	56880	0
12	300.36	6702.0	74	44.96	211862	0	1714	0	0	0	0.00	190	15.12	696	84.82	0	0.00	19	5.28	0	0.00	12.65	34	0	10140	56880	0
12	301.06	6702.0	74	286.98	229326	0	1823	0	0	0	0.00	190	15.12	696	84.79	0	0.00	24	6.67	0	0.00	10.62	24	0	10140	56880	0
12	300.27	6702.0	72	273.41	227711	0	1863	0	0	0	0.00	190	15.12	696	84.79	0	0.00	22	6.11	0	0.00	12.62	24	0	10140	56880	0
12	300.38	6698.0	73	205.46	209548	0	1686	0	0	0	0.00	186	15.06	696	84.79	0	0.00	17	4.72	0	0.00	12.00	27	0	10100	56880	0
12	300.43	6702.0	70	242.41	217929	0	1761	0	0	0	0.00	190	15.11	696	84.74	0	0.00	21	5.83	0	0.00	10.42	36	0	10140	56880	0
12	300.51	6696.0	73	128.92	219646	0	1789	0	0	0	0.00	192	15.03	696	84.82	0	0.00	22	6.11	0	0.00	12.77	27	0	10080	56880	0
12	300.27	6696.0	71	261.31	229340	0	1784	0	0	0	0.00	192	15.03	696	84.82	0	0.00	19	5.28	0	0.00	12.77	34	0	10080	56880	0
12	300.39	6692.0	73	32.28	225541	0	1827	0	0	0	0.00	188	14.97	696	84.79	0	0.00	21	5.83	0	0.00	12.35	31	0	10040	56880	0
36	317.69	6702.0	73	251.85	241646	0	1839	0	0	0	0.00	190	15.10	696	84.69	0	0.00	21	5.83	0	0.00	9.35	31	0	10140	56880	0
36	315.18	6702.0	70	91.21	246077	0	1935	0	0	0	0.00	190	15.11	696	84.74	0	0.00	20	5.56	0	0.00	11.77	26	0	10140	56880	0
36	301.55	6698.0	71	32.85	235878	0	1889	0	0	0	0.00	186	15.05	696	84.74	0	0.00	22	6.11	0	0.00	11.04	30	0	10100	56880	0
36	308.69	6702.0	71	161.71	240574	0	1938	0	0	0	0.00	190	15.11	696	84.74	0	0.00	19	5.28	0	0.00	11.27	34	0	10140	56880	0
36	308.35	6702.0	72	79.92	238697	0	1906	0	0	0	0.00	190	15.12	696	84.79	0	0.00	22	6.11	0	0.00	13.23	36	0	10140	56880	0
36	312.08	6702.0	73	142.62	239722	0	1927	0	0	0	0.00	190	15.12	696	84.79	0	0.00	26	7.22	0	0.00	12.85	32	0	10140	56880	0
36	315.04	6700.0	73	43.91	245286	0	1967	0	0	0	0.00	196	15.09	696	84.79	0	0.00	20	5.56	0	0.00	13.73	32	0	10120	56880	0
36	311.17	6700.0	71	287.41	241105	0	1910	0	0	0	0.00	196	15.09	696	84.82	0	0.00	25	6.94	0	0.00	12.04	27	0	10120	56880	0
36	310.97	6698.0	72	149.26	243344	0	1889	0	0	0	0.00	186	15.04	696	84.69	0	0.00	17	4.72	0	0.00	13.23	32	0	10100	56880	0
36	312.67	6698.0	74	65.94	237911	0	1827	0	0	0	0.00	186	15.05	696	84.77	0	0.00	18	5.00	0	0.00	13.00	32	0	10100	56880	0
36*	300.99	6702.0	71	57.97	234012	0	1867	0	0	0	0.00	190	15.13	696	84.87	0	0.00	22	6.11	0	0.00	14.58	34	0	10140	56880	0
36*	301.38	6698.0	71	175.63	231911	0	1892	0	0	0	0.00	186	15.08	696	84.92	0	0.00	22	6.11	0	0.00	11.04	30	0	10100	56880	0
36*	301.19	6702.0	74	70.70	232583	0	1920	0	0	0	0.00	190	15.13	696	84.87	0	0.00	17	4.72	0	0.00	12.38	39	0	10140	56880	0
36*	300.96	6702.0	73	111.23	231583	0	1863	0	0	0	0.00	190	15.13	696	84.87	0	0.00	17	4.72	0	0.00	12.73	34	0	10140	56880	0
36*	301.35	6702.0	72	158.86	223895	0	1776	0	0	0	0.00	190	15.13	696	84.87	0	0.00	20	5.56	0	0.00	12.38	31	0	10140	56880	0
36*	305.96	6702.0	70	74.69	232285	0	1803	0	0	0	0.00	190	15.13	696	84.87	0	0.00	19	5.28	0	0.00	11.92	27	0	10140	56880	0
36*	301.10	6702.0	69	266.23	229483	0	1806	0	0	0	0.00	190	15.13	696	84.87	0	0.00	24	6.67	0	0.00	10.65	31	0	10140	56880	0
36*	301.14	6700.0	73	12.06	234876	0	1932	0	0	0	0.00	196	15.10	696	84.90	0	0.00	20	5.56	0	0.00	13.73	32	0	10120	56880	0
36*	301.02	6702.0	76	106.30	236356	0	1864	0	0	0	0.00	190	15.13	696	84.87	0	0.00	17	4.72	0	0.00	9.12	21	0	10140	56880	0
36*	301.19	6698.0	72	82.07	231662	0	1884	0	0	0	0.00	186	15.08	696	84.92	0	0.00	17	4.72	0	0.00	13.23	32	0	10100	56880	0

Table D.57: Results of all runs made with GBN network case 6, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.52	6618.0	80	292.72	10312	0	10312	6775	0	0	0.00	570	49.59	388	50.41	0	0.00	28	2.25	0	0.00	11.23	31	0	32820	33360	0
1	300.28	6624.0	80	240.90	10505	0	10505	7008	0	0	0.00	568	49.64	388	50.36	0	0.00	30	2.42	0	0.00	9.27	35	0	32880	33360	0
1	300.50	6620.0	80	191.60	10713	0	10713	7129	0	0	0.00	564	49.61	388	50.39	0	0.00	26	2.09	0	0.00	9.38	36	0	32840	33360	0
1	300.28	6614.0	80	260.64	10332	0	10332	6747	0	0	0.00	566	49.56	388	50.44	0	0.00	26	2.09	0	0.00	10.04	32	0	32780	33360	0
1	300.28	6604.0	80	98.67	10343	0	10343	6804	0	0	0.00	564	49.49	388	50.51	0	0.00	30	2.42	0	0.00	10.27	31	0	32680	33360	0
1	300.52	6622.0	80	265.43	10387	0	10387	6855	0	0	0.00	574	49.62	388	50.38	0	0.00	28	2.25	0	0.00	10.88	32	0	32860	33360	0
1	300.32	6626.0	80	93.16	10208	0	10208	6623	0	0	0.00	562	49.65	388	50.35	0	0.00	25	2.01	0	0.00	10.27	34	0	32900	33360	0
1	300.55	6620.0	80	46.91	10325	0	10325	6783	0	0	0.00	564	49.61	388	50.39	0	0.00	28	2.25	0	0.00	9.31	29	0	32840	33360	0
1	300.28	6620.0	80	142.79	10444	0	10444	6958	0	0	0.00	564	49.61	388	50.39	0	0.00	25	2.01	0	0.00	10.04	30	0	32840	33360	0
1	300.28	6612.0	80	160.06	10484	0	10484	6963	0	0	0.00	572	49.55	388	50.45	0	0.00	28	2.25	0	0.00	9.50	35	0	32760	33360	0
12	300.33	6604.0	80	160.40	105273	0	105273	69238	0	0	0.00	564	49.44	388	50.47	0	0.00	25	2.01	0	0.00	10.62	31	0	32680	33360	0
12	300.58	6596.0	80	142.46	106344	0	106344	70422	0	0	0.00	572	49.42	388	50.58	0	0.00	27	2.17	0	0.00	9.38	26	0	32600	33360	0
12	300.35	6602.0	80	208.21	102138	0	102138	67302	0	0	0.00	570	49.25	388	50.30	0	0.00	29	2.33	0	0.00	10.62	33	0	32660	33360	0
12	300.58	6612.0	80	157.67	103818	0	103818	68449	0	0	0.00	572	49.47	388	50.38	0	0.00	32	2.58	0	0.00	9.23	38	0	32760	33360	0
12	300.33	6604.0	80	85.27	104188	0	104188	68792	0	0	0.00	564	49.40	388	50.42	0	0.00	25	2.01	0	0.00	10.58	34	0	32680	33360	0
12	300.58	6616.0	80	69.08	105387	0	105387	69638	0	0	0.00	576	49.53	388	50.38	0	0.00	29	2.33	0	0.00	7.12	23	0	32800	33360	0
12	300.55	6610.0	80	57.39	105589	0	105589	69710	0	0	0.00	562	49.47	388	50.41	0	0.00	32	2.58	0	0.00	10.31	28	0	32740	33360	0
12	300.33	6614.0	80	51.34	109670	0	109670	72602	0	0	0.00	566	49.55	388	50.42	0	0.00	20	1.61	0	0.00	9.27	32	0	32780	33360	0
12	300.60	6616.0	80	95.64	101501	0	101501	66947	0	0	0.00	560	49.55	388	50.39	0	0.00	25	2.01	0	0.00	10.31	35	0	32800	33360	0
12	300.46	6598.0	80	217.93	102866	0	102866	67812	0	0	0.00	566	49.44	388	50.56	0	0.00	31	2.50	0	0.00	12.15	34	0	32620	33360	0
36	307.96	6604.0	80	274.09	108683	0	108683	71650	0	0	0.00	564	49.25	388	50.27	0	0.00	25	2.01	0	0.00	9.62	30	0	32680	33360	0
36	317.13	6604.0	80	112.60	101862	0	101862	67175	0	0	0.00	564	49.31	388	50.33	0	0.00	30	2.42	0	0.00	10.27	31	0	32680	33360	0
36	311.44	6606.0	80	203.21	107457	0	107457	70756	0	0	0.00	574	49.31	388	50.30	0	0.00	33	2.66	0	0.00	10.46	26	0	32700	33360	0
36	308.57	6612.0	80	58.92	109418	0	109418	72530	0	0	0.00	556	49.47	388	50.38	0	0.00	27	2.17	0	0.00	10.15	31	0	32760	33360	0
36	315.17	6604.0	80	210.49	104512	0	104512	69128	0	0	0.00	564	49.40	388	50.42	0	0.00	23	1.85	0	0.00	10.00	32	0	32680	33360	0
36	312.23	6606.0	80	101.39	111085	0	111085	73280	0	0	0.00	574	49.31	388	50.30	0	0.00	32	2.58	0	0.00	7.54	26	0	32700	33360	0
36	316.38	6610.0	80	114.74	100008	0	100008	66175	0	0	0.00	562	49.41	388	50.35	0	0.00	26	2.09	0	0.00	10.46	28	0	32740	33360	0
36	309.25	6608.0	80	49.67	99729	0	99729	65831	0	0	0.00	568	49.34	388	50.30	0	0.00	25	2.01	0	0.00	10.19	31	0	32720	33360	0
36	317.68	6614.0	80	50.79	112003	0	112003	74046	0	0	0.00	566	49.50	388	50.38	0	0.00	20	1.61	0	0.00	9.27	32	0	32780	33360	0
36	307.54	6612.0	80	213.00	100421	0	100421	66162	0	0	0.00	556	49.53	388	50.44	0	0.00	26	2.09	0	0.00	10.35	26	0	32760	33360	0
36*	301.22	6604.0	80	86.92	108353	0	108353	71514	0	0	0.00	564	49.49	388	50.51	0	0.00	27	2.17	0	0.00	7.46	24	0	32680	33360	0
36*	301.19	6614.0	80	260.71	102459	0	102459	67422	0	0	0.00	566	49.56	388	50.44	0	0.00	29	2.33	0	0.00	10.81	29	0	32780	33360	0
36*	301.47	6608.0	80	127.03	103271	0	103271	68025	0	0	0.00	568	49.52	388	50.48	0	0.00	27	2.17	0	0.00	9.88	28	0	32720	33360	0
36*	301.03	6602.0	80	60.12	106231	0	106231	70111	0	0	0.00	570	49.47	388	50.53	0	0.00	26	2.09	0	0.00	9.35	30	0	32660	33360	0
36*	301.05	6606.0	80	23.23	97909	0	97909	64294	0	0	0.00	574	49.50	388	50.50	0	0.00	28	2.25	0	0.00	10.27	25	0	32700	33360	0
36*	301.25	6596.0	80	133.68	105823	0	105823	69765	0	0	0.00	572	49.42	388	50.58	0	0.00	27	2.17	0	0.00	9.38	26	0	32600	33360	0
36*	301.11	6612.0	80	17.67	107526	0	107526	71184	0	0	0.00	556	49.55	388	50.45	0	0.00	25	2.01	0	0.00	9.31	33	0	32760	33360	0
36*	301.31	6618.0	80	104.16	100112	0	100112	66039	0	0	0.00	570	49.59	388	50.41	0	0.00	25	2.01	0	0.00	9.54	27	0	32820	33360	0
36*	301.02	6612.0	80	204.08	108640	0	108640	71604	0	0	0.00	572	49.55	388	50.45	0	0.00	30	2.42	0	0.00	9.69	36	0	32760	33360	0
36*	300.88	6608.0	80	22.01	102413	0	102413	67653	0	0	0.00	568	49.52	388	50.48	0	0.00	25	2.01	0	0.00	10.19	31	0	32720	33360	0

Table D.58: Results of all runs made with GBN network case 7, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.28	7266.0	80	42.20	6724	0	6724	1562	0	0	0.00	288	23.78	734	76.22	0	0.00	28	4.51	0	0.00	6.85	26	0	17280	55380	0
1	300.60	7270.0	80	238.13	6600	0	6599	1504	0	0	0.00	292	23.82	734	76.18	0	0.00	28	4.51	0	0.00	7.23	29	0	17320	55380	0
1	300.35	7254.0	80	238.71	6593	0	6593	1517	0	0	0.00	292	23.66	734	76.34	0	0.00	25	4.03	0	0.00	7.73	25	0	17160	55380	0
1	300.53	7264.0	80	50.45	6647	0	6647	1476	0	0	0.00	294	23.76	734	76.24	0	0.00	29	4.67	0	0.00	7.38	25	0	17260	55380	0
1	300.32	7248.0	80	9.78	6643	0	6643	1516	0	0	0.00	294	23.59	734	76.41	0	0.00	29	4.67	0	0.00	6.88	18	0	17100	55380	0
1	300.53	7258.0	80	66.63	6611	0	6611	1458	0	0	0.00	296	23.70	734	76.30	0	0.00	24	3.86	0	0.00	8.38	27	0	17200	55380	0
1	300.53	7258.0	80	159.99	6578	0	6577	1477	0	0	0.00	296	23.70	734	76.30	0	0.00	27	4.35	0	0.00	6.42	30	0	17200	55380	0
1	300.28	7270.0	80	164.27	6773	0	6772	1536	0	0	0.00	292	23.82	734	76.18	0	0.00	26	4.19	0	0.00	7.46	26	0	17320	55380	0
1	300.53	7266.0	80	199.80	6660	0	6660	1558	0	0	0.00	288	23.78	734	76.22	0	0.00	23	3.70	0	0.00	6.12	23	0	17280	55380	0
1	300.30	7262.0	80	25.68	6755	0	6755	1534	0	0	0.00	300	23.74	734	76.26	0	0.00	30	4.83	0	0.00	7.62	30	0	17240	55380	0
12	300.39	7244.0	80	194.52	56503	0	56501	12847	0	0	0.00	290	23.51	734	76.30	0	0.00	25	4.03	0	0.00	7.50	25	0	17060	55380	0
12	300.47	7256.0	80	201.74	50255	0	50253	11617	0	0	0.00	286	23.65	734	76.24	0	0.00	29	4.67	0	0.00	7.12	23	0	17180	55380	0
12	300.63	7258.0	80	46.32	49612	0	49611	11207	0	0	0.00	296	23.70	734	76.30	0	0.00	24	3.86	0	0.00	6.08	27	0	17200	55380	0
12	300.38	7256.0	80	19.39	43015	0	43013	10023	0	0	0.00	302	23.67	734	76.30	0	0.00	26	4.19	0	0.00	7.31	39	0	17180	55380	0
12	300.50	7254.0	80	15.04	59472	0	59470	13796	0	0	0.00	292	23.61	734	76.20	0	0.00	26	4.19	0	0.00	9.92	30	0	17160	55380	0
12	300.52	7254.0	80	175.36	53388	0	53386	12230	0	0	0.00	292	23.64	734	76.30	0	0.00	26	4.19	0	0.00	7.88	32	0	17160	55380	0
12	300.80	7258.0	80	131.17	60125	0	60122	13812	0	0	0.00	296	23.64	734	76.11	0	0.00	25	4.03	0	0.00	7.42	32	0	17200	55380	0
12	300.60	7256.0	80	62.03	46399	0	46398	10717	0	0	0.00	302	23.62	734	76.16	0	0.00	30	4.83	0	0.00	7.85	29	0	17180	55380	0
12	300.80	7248.0	80	200.88	44844	0	44844	10402	0	0	0.00	294	23.53	734	76.22	0	0.00	28	4.51	0	0.00	6.96	28	0	17100	55380	0
12	300.69	7246.0	80	34.29	55687	0	55686	12732	0	0	0.00	284	23.53	734	76.30	0	0.00	26	4.19	0	0.00	6.88	26	0	17080	55380	0
36	307.82	7258.0	80	4.60	67089	0	67084	15443	0	0	0.00	296	23.67	734	76.20	0	0.00	28	4.51	0	0.00	6.46	24	0	17200	55380	0
36	308.90	7248.0	80	53.45	63261	0	63259	14590	0	0	0.00	294	23.54	734	76.24	0	0.00	29	4.67	0	0.00	6.88	18	0	17100	55380	0
36	314.26	7248.0	80	278.87	65448	0	65446	15106	0	0	0.00	294	23.53	734	76.22	0	0.00	23	3.70	0	0.00	6.12	26	0	17100	55380	0
36	311.69	7251.6	80	40.31	62145	0	62144	14274	0	0	0.00	296	23.46	734	76.24	1	0.13	25	4.03	0	0.00	6.42	19	0	17040	55380	96
36	309.78	7246.0	80	136.33	63950	0	63949	14582	0	0	0.00	284	23.47	734	76.09	0	0.00	26	4.19	0	0.00	6.88	26	0	17080	55380	0
36	313.44	7252.0	80	70.87	66940	0	66937	15419	0	0	0.00	298	23.54	734	76.07	0	0.00	31	4.99	0	0.00	5.46	24	0	17140	55380	0
36	316.01	7228.0	80	2.17	70851	0	70850	16456	0	0	0.00	290	23.21	734	76.07	0	0.00	27	4.35	0	0.00	6.73	24	0	16900	55380	0
36	324.04	7250.0	80	83.83	58494	0	58452	13477	0	0	0.00	304	23.55	734	76.18	0	0.00	26	4.19	0	0.00	8.38	31	0	17120	55380	0
36	312.76	7246.0	80	240.51	59319	0	59317	13547	0	0	0.00	284	23.51	734	76.22	0	0.00	31	4.99	0	0.00	5.88	21	0	17080	55380	0
36	306.79	7244.0	80	174.64	66769	0	66768	15314	0	0	0.00	290	23.45	734	76.11	0	0.00	29	4.67	0	0.00	8.12	32	0	17060	55380	0
36*	301.45	7256.0	80	183.43	70422	0	70420	16142	0	0	0.00	302	23.68	734	76.32	0	0.00	29	4.67	0	0.00	5.54	20	0	17180	55380	0
36*	301.24	7252.0	80	58.22	72275	0	72275	16547	0	0	0.00	298	23.63	734	76.37	0	0.00	27	4.35	0	0.00	7.12	27	0	17140	55380	0
36*	301.47	7256.0	80	92.76	71063	0	71059	16445	0	0	0.00	302	23.68	734	76.32	0	0.00	30	4.83	0	0.00	4.85	17	0	17180	55380	0
36*	300.97	7254.0	80	47.41	70748	0	70745	16151	0	0	0.00	292	23.66	734	76.34	0	0.00	25	4.03	0	0.00	8.35	28	0	17160	55380	0
36*	326.76	7250.0	80	30.12	75129	0	75125	17241	0	0	0.00	288	23.61	734	76.39	0	0.00	29	4.67	0	0.00	6.50	22	0	17120	55380	0
36*	313.51	7254.0	80	42.43	70938	0	70937	16361	0	0	0.00	308	23.66	734	76.34	0	0.00	29	4.67	0	0.00	5.38	19	0	17160	55380	0
36*	325.99	7248.0	80	31.67	73844	0	73843	16846	0	0	0.00	294	23.59	734	76.41	0	0.00	29	4.67	0	0.00	6.88	18	0	17100	55380	0
36*	301.00	7254.0	80	215.20	71579	0	71579	16644	0	0	0.00	292	23.66	734	76.34	0	0.00	24	3.86	0	0.00	7.65	29	0	17160	55380	0
36*	301.41	7238.0	80	156.64	71810	0	71809	16655	0	0	0.00	292	23.49	734	76.51	0	0.00	27	4.35	0	0.00	8.77	29	0	17000	55380	0
36*	308.51	7256.0	80	217.12	71952	0	71950	16358	0	0	0.00	302	23.68	734	76.32	0	0.00	25	4.03	0	0.00	6.46	27	0	17180	55380	0

Table D.59: Results of all runs made with GBN network case 8, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.61	7944.0	80	219.27	3715	0	3715	3	0	0	0.00	232	21.98	742	78.02	0	0.00	34	8.21	0	0.00	11.35	43	0	17460	61980	0
1	300.32	7944.0	80	169.79	3692	0	3692	0	0	0	0.00	226	22.28	738	77.72	0	0.00	39	9.42	0	0.00	11.96	38	0	17700	61740	0
1	300.36	7928.0	80	149.23	3719	0	3719	0	0	0	0.00	232	21.82	742	78.18	0	0.00	32	7.73	0	0.00	8.04	30	0	17300	61980	0
1	300.30	7936.0	80	151.05	3689	0	3689	1	0	0	0.00	244	22.51	734	77.50	0	0.00	35	8.45	0	0.00	9.23	33	0	17860	61500	0
1	300.61	7956.0	80	83.35	3703	0	3703	0	0	0	0.00	230	22.10	742	77.90	0	0.00	35	8.45	0	0.00	10.04	43	0	17580	61980	0
1	300.39	7948.0	80	101.40	3668	0	3668	0	0	0	0.00	222	22.77	732	77.23	0	0.00	38	9.18	0	0.00	11.19	45	0	18100	61380	0
1	300.66	7952.0	80	30.70	3698	0	3698	1	0	0	0.00	238	22.21	740	77.79	0	0.00	34	8.21	0	0.00	9.23	39	0	17660	61860	0
1	300.63	7962.0	80	67.61	3677	0	3677	2	0	0	0.00	244	22.91	732	77.09	0	0.00	36	8.70	0	0.00	9.77	40	0	18240	61380	0
1	300.36	7944.0	80	225.83	3695	0	3695	1	0	0	0.00	250	23.49	722	76.51	0	0.00	29	7.00	0	0.00	9.23	41	0	18660	60780	0
1	300.63	7956.0	80	294.56	3683	0	3683	0	0	0	0.00	236	22.55	736	77.45	0	0.00	29	7.00	0	0.00	7.81	34	0	17940	61620	0
12	300.69	7930.0	80	107.11	38952	0	38952	12	0	0	0.00	236	22.09	738	77.68	0	0.00	36	8.70	0	0.00	10.23	41	0	17560	61740	0
12	300.67	7926.0	80	226.87	37734	0	37734	13	0	0	0.00	232	22.00	738	77.54	0	0.00	43	10.39	0	0.00	10.15	37	0	17520	61740	0
12	300.44	7942.0	80	228.90	36728	0	36728	12	0	0	0.00	240	22.65	732	77.05	0	0.00	34	8.21	0	0.00	10.00	38	0	18040	61380	0
12	300.41	7936.0	80	65.91	38920	0	38920	18	0	0	0.00	224	21.10	752	78.70	0	0.00	37	8.94	0	0.00	9.42	38	0	16780	62580	0
12	300.67	7932.0	80	295.09	38350	0	38350	12	0	0	0.00	236	21.78	742	77.84	0	0.00	35	8.45	0	0.00	9.73	38	0	17340	61980	0
12	300.64	7932.0	80	114.97	37664	0	37664	16	0	0	0.00	216	21.19	750	78.51	0	0.00	38	9.18	0	0.00	10.54	32	0	16860	62460	0
12	300.67	7932.0	80	128.45	38639	0	38639	10	0	0	0.00	234	21.95	740	77.75	0	0.00	36	8.70	0	0.00	11.65	35	0	17460	61860	0
12	300.41	7934.0	80	161.98	36010	0	36010	7	0	0	0.00	234	22.41	734	77.26	0	0.00	35	8.45	0	0.00	8.31	30	0	17840	61500	0
12	300.69	7934.0	80	293.03	37245	0	37245	2878	0	0	0.00	244	22.76	730	77.11	0	0.00	32	7.73	0	0.00	10.69	38	0	18080	61260	0
12	300.57	7942.0	80	183.28	36768	0	36768	18	0	0	0.00	242	22.52	734	77.30	0	0.00	41	9.90	0	0.00	10.88	39	0	17920	61500	0
36	314.03	7924.0	80	83.35	40837	0	40837	9	0	0	0.00	248	22.29	734	77.28	0	0.00	37	8.94	0	0.00	10.19	31	0	17740	61500	0
36	317.90	7922.0	80	97.63	41386	0	41386	18	0	0	0.00	228	21.92	738	77.41	0	0.00	34	8.21	0	0.00	9.12	34	0	17480	61740	0
36	317.37	7934.0	80	297.13	39214	0	39214	141	0	0	0.00	230	21.79	742	77.79	0	0.00	38	9.18	0	0.00	10.15	41	0	17360	61980	0
36	315.20	7920.0	80	295.90	40566	0	40566	12	0	0	0.00	242	22.37	732	77.05	0	0.00	32	7.73	0	0.00	9.46	29	0	17820	61380	0
36	313.37	7934.0	80	144.13	41336	0	41336	11	0	0	0.00	234	22.35	734	77.05	0	0.00	35	8.45	0	0.00	8.31	30	0	17840	61500	0
36	308.68	7938.0	80	289.07	573699	0	573699	3	0	0	0.00	238	22.40	734	77.05	0	0.00	32	7.73	0	0.00	9.46	35	0	17880	61500	0
36	313.45	7941.6	80	193.04	40345	0	40345	13	0	0	0.00	224	21.57	744	77.78	1	0.12	36	8.70	0	0.00	10.31	36	0	17220	62100	96
36	307.88	7922.0	80	286.93	40052	0	40052	9	0	0	0.00	224	21.46	746	78.54	0	0.00	36	8.70	0	0.00	10.62	41	0	17000	62220	0
36	313.83	7932.0	80	291.85	38223	0	38223	9	0	0	0.00	224	21.71	744	78.29	0	0.00	42	10.14	0	0.00	10.81	38	0	17220	62100	0
36	314.43	7932.0	80	98.75	39169	0	39169	12	0	0	0.00	240	22.47	734	77.53	0	0.00	36	8.70	0	0.00	9.96	42	0	17820	61500	0
36*	301.13	7940.0	80	25.49	37659	0	37659	11	0	0	0.00	236	23.15	726	76.85	0	0.00	38	9.18	0	0.00	13.08	45	0	18380	61020	0
36*	301.53	7930.0	80	124.97	38858	0	38858	14	0	0	0.00	226	21.84	742	78.16	0	0.00	38	9.18	0	0.00	9.62	41	0	17320	61980	0
36*	301.58	7948.0	80	96.41	37978	0	37978	10	0	0	0.00	238	22.77	732	77.23	0	0.00	34	8.21	0	0.00	11.27	37	0	18100	61380	0
36*	301.44	7930.0	80	53.68	39403	0	39403	14	0	0	0.00	240	22.75	730	77.25	0	0.00	32	7.73	0	0.00	10.08	39	0	18040	61260	0
36*	300.92	7930.0	80	186.37	38895	0	38895	8	0	0	0.00	222	21.24	750	78.76	0	0.00	41	9.90	0	0.00	8.85	35	0	16840	62460	0
36*	301.24	7940.0	80	17.24	38717	0	38717	17	0	0	0.00	236	23.15	726	76.85	0	0.00	36	8.70	0	0.00	6.81	34	0	18380	61020	0
36*	301.44	7932.0	80	29.22	38323	0	38323	12	0	0	0.00	234	22.01	740	77.99	0	0.00	31	7.49	0	0.00	9.58	36	0	17460	61860	0
36*	301.17	7932.0	80	123.96	36719	0	36719	11	0	0	0.00	240	22.47	734	77.53	0	0.00	36	8.70	0	0.00	9.96	42	0	17820	61500	0
36*	309.57	7936.0	80	46.15	39575	0	39575	11	0	0	0.00	228	22.51	734	77.50	0	0.00	37	8.94	0	0.00	9.19	41	0	17860	61500	0
36*	301.38	7922.0	80	231.26	38623	0	38623	7	0	0	0.00	224	21.46	746	78.54	0	0.00	36	8.70	0	0.00	10.62	41	0	17000	62220	0

Table D.60: Results of all runs made with GBN network case 9, in 300 seconds.

D.7 NSF, Given 60 Seconds

Symbol	Name
$\#T$	Number of Threads
t_E	Time of Execution
C	Best Cost Solution found
CA	Highest Channel Assigned
t_{sol}	Found Solution Time
$\#i$	Number of Iterations
$\#IS$	Number of Invalid Solutions
$\#G_U$	Number of Greedy Solutions Unfeasible
$\#LS_U$	Number of Local Search Solutions Unfeasible
UD	Unfeasible Degree
$\#IM$	Number of Invert Multiplex used
C_{IM}	Cost % of Invert Multiplex
$\#MX$	Number of Muxponders placed
C_{MX}	Cost % of Muxponders
$\#TX$	Number of Transponders placed
C_{TX}	Cost % of Transponders
$\#3R$	Number of $3R$ regenerators placed
C_{3R}	Cost % of $3R$ regenerators
#10	Number of Multi-Hop Grooming of $10Gb/s$
%10	Traffic % of Multi-Hop Grooming of $10Gb/s$
#40	Number of Multi-hop Grooming of $40Gb/s$
%40	Traffic % of Multi-hop Grooming of $40Gb/s$
$\bar{m}F$	Average Fragmentation at Channel Assigned
MF	Max Fragmentation at Channel Assigned
C_{IM}	Cost of Invert Multiplexers
C_{MX}	Cost of Multiplexers
C_{TX}	Cost of Transponders
C_{3R}	Cost of $3R$ regenerators

Table D.61: Header symbols and their description.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.12	4440.4	59	8.61	25624	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	10	1.67	0	0.00	4.00	29	2800	15480	9900	16224
1	60.22	4440.4	59	7.46	25675	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	8	1.33	0	0.00	4.05	29	2800	15480	9900	16224
1	60.14	4440.4	59	5.43	25606	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	7	1.17	0	0.00	4.55	29	2800	15480	9900	16224
1	60.22	4440.4	59	10.14	25673	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	6	1.00	0	0.00	4.25	29	2800	15480	9900	16224
1	60.15	4440.4	59	1.86	25635	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	10	1.67	0	0.00	4.90	26	2800	15480	9900	16224
1	60.22	4440.4	59	1.79	25678	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	7	1.17	0	0.00	4.75	29	2800	15480	9900	16224
1	60.12	4440.4	59	24.62	25621	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	7	1.17	0	0.00	3.70	28	2800	15480	9900	16224
1	60.23	4440.4	59	22.78	25703	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	10	1.67	0	0.00	5.50	29	2800	15480	9900	16224
1	60.14	4440.4	59	14.94	25621	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	7	1.17	0	0.00	4.60	29	2800	15480	9900	16224
1	60.23	4440.4	59	20.62	25707	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	7	1.17	0	0.00	4.30	26	2800	15480	9900	16224
12	60.25	4440.4	59	0.28	238450	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	6	1.00	0	0.00	4.20	29	2800	15480	9900	16224
12	60.15	4440.4	59	0.02	242412	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	6	1.00	0	0.00	4.80	29	2800	15480	9900	16224
12	60.23	4440.4	59	2.26	233856	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	7	1.17	0	0.00	4.50	29	2800	15480	9900	16224
12	60.14	4440.4	59	0.97	250725	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	7	1.17	0	0.00	4.75	29	2800	15480	9900	16224
12	60.25	4440.4	59	2.23	237102	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	7	1.17	0	0.00	4.65	18	2800	15480	9900	16224
12	60.15	4440.4	59	2.68	250100	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	7	1.17	0	0.00	4.15	29	2800	15480	9900	16224
12	60.14	4440.4	59	2.01	233062	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	6	1.00	0	0.00	4.20	27	2800	15480	9900	16224
12	60.23	4440.4	59	0.25	239579	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	9	1.50	0	0.00	4.35	28	2800	15480	9900	16224
12	60.15	4440.4	59	1.76	225783	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	8	1.33	0	0.00	4.05	28	2800	15480	9900	16224
12	60.25	4440.4	59	0.39	237168	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	8	1.33	0	0.00	5.15	22	2800	15480	9900	16224
36	69.72	4440.4	59	0.03	301306	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	7	1.17	0	0.00	5.25	29	2800	15480	9900	16224
36	62.76	4438.8	59	14.71	277932	0	0	0	0	14	6.31	308	35.04	126	22.30	159	36.32	12	2.00	0	0.00	4.90	29	2800	15560	9900	16128
36	75.35	4440.4	59	0.80	323673	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	7	1.17	0	0.00	4.15	28	2800	15480	9900	16224
36	72.45	4440.4	59	1.11	303973	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	6	1.00	0	0.00	4.05	29	2800	15480	9900	16224
36	76.53	4440.4	59	1.14	330729	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	6	1.00	0	0.00	4.55	29	2800	15480	9900	16224
36	74.32	4440.4	59	0.44	321334	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	8	1.33	0	0.00	4.45	29	2800	15480	9900	16224
36	67.28	4440.4	59	0.09	291172	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	8	1.33	0	0.00	4.35	25	2800	15480	9900	16224
36	65.79	4440.4	59	0.67	287575	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	9	1.50	0	0.00	4.50	29	2800	15480	9900	16224
36	68.31	4440.4	59	1.53	296374	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	8	1.33	0	0.00	4.05	29	2800	15480	9900	16224
36	69.20	4440.4	59	3.00	289600	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	8	1.33	0	0.00	4.60	28	2800	15480	9900	16224
36*	74.19	4440.4	59	0.58	308485	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	6	1.00	0	0.00	4.20	29	2800	15480	9900	16224
36*	73.66	4440.4	59	0.08	282222	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	8	1.33	0	0.00	4.65	29	2800	15480	9900	16224
36*	60.98	4440.4	59	2.37	253551	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	7	1.17	0	0.00	4.65	18	2800	15480	9900	16224
36*	70.87	4438.8	60	43.26	296947	0	0	0	0	14	6.31	308	35.05	126	22.30	159	36.33	11	1.83	0	0.00	4.70	26	2800	15560	9900	16128
36*	71.15	4440.4	59	0.27	306912	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	7	1.17	0	0.00	3.95	29	2800	15480	9900	16224
36*	73.35	4440.4	59	1.12	303042	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	8	1.33	0	0.00	5.15	22	2800	15480	9900	16224
36*	67.39	4440.4	59	4.84	288613	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	6	1.00	0	0.00	4.60	24	2800	15480	9900	16224
36*	74.22	4440.4	59	5.21	307934	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	6	1.00	0	0.00	4.75	20	2800	15480	9900	16224
36*	72.73	4440.4	59	1.51	310633	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	6	1.00	0	0.00	4.70	30	2800	15480	9900	16224
36*	73.55	4440.4	59	0.58	320683	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	6	1.00	0	0.00	4.05	29	2800	15480	9900	16224

Table D.62: Results of all runs made with NSF network case 1, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.15	4897.6	61	56.47	19551	0	0	0	0	16	6.53	154	16.70	334	47.17	142	29.60	11	3.67	0	0.00	4.30	25	3200	8180	23100	14496
1	60.23	4892.4	61	48.95	19549	0	0	0	0	16	6.54	152	16.52	334	47.22	141	29.73	11	3.67	0	0.00	3.85	29	3200	8080	23100	14544
1	60.14	4892.4	62	58.27	19558	0	0	0	0	16	6.54	152	16.52	334	47.22	141	29.73	11	3.67	0	0.00	4.95	28	3200	8080	23100	14544
1	60.23	4896.4	63	37.89	19476	0	0	0	0	16	6.54	156	16.58	334	47.18	141	29.70	11	3.67	0	0.00	5.60	28	3200	8120	23100	14544
1	60.14	4902.0	61	1.58	19516	0	0	0	0	16	6.53	152	16.48	334	47.12	142	29.87	8	2.67	0	0.00	6.65	35	3200	8080	23100	14640
1	60.23	4897.6	61	18.35	19528	0	0	0	0	16	6.53	154	16.70	334	47.17	142	29.60	13	4.33	0	0.00	5.50	28	3200	8180	23100	14496
1	60.14	4892.0	66	49.05	19530	0	0	0	0	16	6.54	158	16.80	334	47.22	141	29.44	11	3.67	0	0.00	5.95	33	3200	8220	23100	14400
1	60.23	4893.6	62	9.63	19498	0	0	0	0	16	6.54	150	16.63	334	47.20	139	29.62	11	3.67	0	0.00	4.75	32	3200	8140	23100	14496
1	60.14	4895.6	61	18.89	19398	0	0	0	0	16	6.54	144	16.67	334	47.19	136	29.61	9	3.00	0	0.00	5.40	28	3200	8160	23100	14496
1	60.23	4895.6	61	2.96	19552	0	0	0	0	16	6.54	144	16.67	334	47.19	136	29.61	11	3.67	0	0.00	5.30	28	3200	8160	23100	14496
12	60.25	4887.6	61	8.66	182298	0	0	0	0	16	6.54	152	16.50	334	47.19	142	29.61	11	3.67	0	0.00	5.80	29	3200	8080	23100	14496
12	60.14	4889.2	62	12.89	192667	0	0	0	0	16	6.53	152	16.82	334	47.16	139	29.30	14	4.67	0	0.00	5.35	26	3200	8240	23100	14352
12	60.25	4888.0	61	35.05	173741	0	0	0	0	16	6.54	154	16.72	334	47.22	141	29.43	12	4.00	0	0.00	5.20	28	3200	8180	23100	14400
12	60.15	4892.4	62	36.80	188244	0	0	0	0	16	6.53	152	16.50	334	47.17	141	29.70	10	3.33	0	0.00	4.70	30	3200	8080	23100	14544
12	60.25	4892.4	61	35.71	193367	0	0	0	0	16	6.54	152	16.50	334	47.18	141	29.70	9	3.00	0	0.00	4.55	29	3200	8080	23100	14544
12	60.14	4892.4	61	46.14	189212	0	0	0	0	16	6.54	152	16.50	334	47.19	141	29.71	10	3.33	0	0.00	4.70	29	3200	8080	23100	14544
12	60.25	4882.8	62	48.91	181148	0	0	0	0	16	6.55	152	16.53	334	47.26	140	29.56	12	4.00	0	0.00	4.85	28	3200	8080	23100	14448
12	60.20	4887.6	61	40.15	192740	0	0	0	0	16	6.53	152	16.48	334	47.12	142	29.57	11	3.67	0	0.00	5.60	31	3200	8080	23100	14496
12	60.26	4888.0	61	13.07	186370	0	0	0	0	16	6.53	154	16.70	334	47.17	141	29.41	13	4.33	0	0.00	4.95	27	3200	8180	23100	14400
12	60.26	4882.8	62	6.07	177795	0	0	0	0	16	6.54	152	16.52	334	47.22	140	29.53	12	4.00	0	0.00	4.85	28	3200	8080	23100	14448
36	70.00	4887.6	61	12.89	229911	0	0	0	0	16	6.54	152	16.52	334	47.22	142	29.63	11	3.67	0	0.00	4.40	28	3200	8080	23100	14496
36	71.99	4882.8	62	10.84	235211	0	0	0	0	16	6.53	152	16.48	334	47.12	140	29.47	13	4.33	0	0.00	5.95	31	3200	8080	23100	14448
36	74.96	4887.6	61	6.80	245345	0	0	0	0	16	6.53	152	16.50	334	47.17	142	29.60	11	3.67	0	0.00	5.85	28	3200	8080	23100	14496
36	72.21	4882.8	62	58.56	237303	0	0	0	0	16	6.54	152	16.52	334	47.22	140	29.53	12	4.00	0	0.00	4.65	29	3200	8080	23100	14448
36	76.74	4887.6	61	52.74	251800	0	0	0	0	16	6.53	152	16.50	334	47.17	142	29.60	11	3.67	0	0.00	5.80	31	3200	8080	23100	14496
36	76.55	4892.0	64	49.25	251361	0	0	0	0	16	6.53	158	16.79	334	47.17	141	29.40	13	4.33	0	0.00	5.55	30	3200	8220	23100	14400
36	68.28	4882.8	62	44.10	226023	0	0	0	0	16	6.54	152	16.50	334	47.18	140	29.51	12	4.00	0	0.00	6.45	37	3200	8080	23100	14448
36	66.19	4888.0	61	34.40	219501	0	0	0	0	16	6.53	154	16.69	334	47.12	141	29.37	10	3.33	0	0.00	5.55	30	3200	8180	23100	14400
36	72.93	4888.0	61	52.65	238850	0	0	0	0	16	6.53	154	16.69	334	47.12	141	29.38	13	4.33	0	0.00	4.90	30	3200	8180	23100	14400
36	70.23	4888.0	61	17.89	237099	0	0	0	0	16	6.53	154	16.69	334	47.13	141	29.38	11	3.67	0	0.00	5.45	31	3200	8180	23100	14400
36*	68.00	4887.6	61	33.17	209144	0	0	0	0	16	6.55	152	16.53	334	47.26	142	29.66	11	3.67	0	0.00	5.80	29	3200	8080	23100	14496
36*	73.71	4891.6	62	27.29	230540	0	0	0	0	16	6.54	156	16.60	334	47.22	142	29.63	10	3.33	0	0.00	5.05	32	3200	8120	23100	14496
36*	61.00	4882.8	62	34.76	205508	0	0	0	0	16	6.55	152	16.55	334	47.31	140	29.59	12	4.00	0	0.00	5.85	29	3200	8080	23100	14448
36*	60.96	4892.4	62	9.14	201528	0	0	0	0	16	6.54	152	16.52	334	47.22	141	29.73	10	3.33	0	0.00	5.40	31	3200	8080	23100	14544
36*	61.01	4888.0	61	34.26	202276	0	0	0	0	16	6.55	154	16.73	334	47.26	141	29.46	13	4.33	0	0.00	4.30	30	3200	8180	23100	14400
36*	69.84	4882.8	62	30.06	216250	0	0	0	0	16	6.55	152	16.55	334	47.31	140	29.59	12	4.00	0	0.00	4.85	28	3200	8080	23100	14448
36*	72.66	4887.6	61	1.22	220703	0	0	0	0	16	6.55	152	16.53	334	47.26	142	29.66	12	4.00	0	0.00	5.15	27	3200	8080	23100	14496
36*	68.53	4882.8	62	11.65	223249	0	0	0	0	16	6.55	152	16.55	334	47.31	140	29.59	13	4.33	0	0.00	5.95	31	3200	8080	23100	14448
36*	73.29	4887.6	61	37.30	241738	0	0	0	0	16	6.55	152	16.53	334	47.26	142	29.66	11	3.67	0	0.00	5.85	28	3200	8080	23100	14496
36*	72.79	4887.6	61	9.75	206979	0	0	0	0	16	6.55	152	16.53	334	47.26	142	29.66	11	3.67	0	0.00	6.35	38	3200	8080	23100	14496

Table D.63: Results of all runs made with NSF network case 2, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.15	5544.0	80	7.18	19909	0	19909	0	0	24	8.66	104	9.96	356	47.62	174	33.77	6	3.00	0	0.00	5.30	31	4800	5520	26400	18720
1	60.25	5544.0	80	2.89	19899	0	19899	0	0	24	8.66	104	9.96	356	47.62	174	33.77	6	3.00	0	0.00	7.60	38	4800	5520	26400	18720
1	60.15	5544.4	80	44.60	19899	0	19899	0	0	24	8.66	106	10.14	356	47.62	173	33.59	8	4.00	0	0.00	6.15	37	4800	5620	26400	18624
1	60.25	5545.2	80	20.81	19903	0	19903	0	0	24	8.66	102	10.06	356	47.61	172	33.67	6	3.00	0	0.00	4.90	30	4800	5580	26400	18672
1	60.15	5542.0	80	35.74	19849	0	19849	0	0	24	8.66	102	10.36	356	47.64	170	33.35	10	5.00	0	0.00	4.70	36	4800	5740	26400	18480
1	60.25	5535.6	80	1.09	19908	0	19908	0	0	24	8.67	102	10.08	356	47.69	171	33.56	8	4.00	0	0.00	5.55	34	4800	5580	26400	18576
1	60.15	5541.6	80	53.07	19941	0	19941	0	0	24	8.66	100	10.18	356	47.64	171	33.52	8	4.00	0	0.00	7.30	38	4800	5640	26400	18576
1	60.24	5545.2	80	9.77	19835	0	19835	0	0	24	8.66	102	10.06	356	47.61	172	33.67	5	2.50	0	0.00	5.60	36	4800	5580	26400	18672
1	60.14	5544.0	80	18.06	19838	0	19838	0	0	24	8.66	104	9.96	356	47.62	174	33.77	8	4.00	0	0.00	5.40	38	4800	5520	26400	18720
1	60.24	5536.8	80	36.66	19883	0	19883	0	0	24	8.67	100	10.19	356	47.68	169	33.46	7	3.50	0	0.00	5.65	38	4800	5640	26400	18528
12	60.14	5534.4	80	21.08	186792	0	186792	0	0	24	8.67	104	9.97	356	47.69	173	33.64	7	3.50	0	0.00	5.25	31	4800	5520	26400	18624
12	60.25	5534.8	80	38.17	195025	0	195025	0	0	24	8.65	106	10.13	356	47.57	172	33.38	9	4.50	0	0.00	4.90	33	4800	5620	26400	18528
12	60.15	5534.4	80	31.90	191839	0	191839	0	0	24	8.66	104	9.96	356	47.62	173	33.59	6	3.00	0	0.00	3.85	29	4800	5520	26400	18624
12	60.27	5536.8	80	56.06	182339	0	182339	0	0	24	8.65	100	10.17	356	47.60	169	33.41	7	3.50	0	0.00	8.90	38	4800	5640	26400	18528
12	60.14	5534.8	80	4.93	199217	0	199217	0	0	24	8.66	106	10.14	356	47.62	172	33.42	7	3.50	0	0.00	5.25	37	4800	5620	26400	18528
12	60.25	5535.6	80	54.98	181188	0	181188	0	0	24	8.66	102	10.06	356	47.62	171	33.50	8	4.00	0	0.00	3.00	27	4800	5580	26400	18576
12	60.16	5534.4	80	2.48	197398	0	197398	0	0	24	8.66	104	9.95	356	47.61	173	33.58	6	3.00	0	0.00	4.40	31	4800	5520	26400	18624
12	60.24	5528.8	80	34.14	192635	0	192635	0	0	24	8.67	108	10.05	356	47.70	172	33.48	8	4.00	0	0.00	4.90	38	4800	5560	26400	18528
12	60.26	5538.4	80	20.37	200802	0	200802	0	0	24	8.66	108	10.03	356	47.63	173	33.60	10	5.00	0	0.00	4.65	34	4800	5560	26400	18624
12	60.23	5535.6	80	17.64	195023	0	195023	0	0	24	8.67	102	10.08	356	47.69	171	33.56	8	4.00	0	0.00	5.80	36	4800	5580	26400	18576
36	73.24	5540.4	80	13.54	242466	0	242466	0	0	24	8.65	102	10.05	356	47.57	173	33.56	6	3.00	0	0.00	4.45	36	4800	5580	26400	18624
36	67.26	5534.4	80	22.63	227215	0	227215	0	0	24	8.66	104	9.96	356	47.62	173	33.59	7	3.50	0	0.00	5.50	35	4800	5520	26400	18624
36	68.83	5534.8	80	6.44	236417	0	236417	0	0	24	8.66	106	10.14	356	47.62	172	33.42	8	4.00	0	0.00	4.60	34	4800	5620	26400	18528
36	74.07	5532.0	80	33.26	251643	0	251643	0	0	24	8.65	100	10.16	356	47.56	170	33.29	10	5.00	0	0.00	5.00	32	4800	5640	26400	18480
36	73.80	5542.8	80	57.50	255036	0	255036	0	0	24	8.66	98	10.28	356	47.62	169	33.42	9	4.50	0	0.00	4.25	34	4800	5700	26400	18528
36	66.24	5534.8	80	35.82	227079	0	227079	0	0	24	8.66	106	10.14	356	47.62	172	33.42	9	4.50	0	0.00	4.95	30	4800	5620	26400	18528
36	72.10	5526.0	80	9.44	242243	0	242243	0	0	24	8.66	102	10.06	356	47.61	170	33.32	6	3.00	0	0.00	5.75	35	4800	5580	26400	18480
36	75.02	5528.8	80	27.43	257691	0	257691	0	0	24	8.66	108	10.03	356	47.61	172	33.41	8	4.00	0	0.00	5.40	35	4800	5560	26400	18528
36	71.46	5538.4	80	3.32	239434	0	239434	0	0	24	8.65	108	10.02	356	47.57	173	33.56	8	4.00	0	0.00	5.25	37	4800	5560	26400	18624
36	70.15	5536.0	80	8.83	239650	0	239650	0	0	24	8.64	104	10.23	356	47.53	170	33.27	9	4.50	0	0.00	5.40	32	4800	5680	26400	18480
36*	75.50	5535.6	80	43.68	233237	0	233237	0	0	24	8.67	102	10.08	356	47.69	171	33.56	8	4.00	0	0.00	3.00	27	4800	5580	26400	18576
36*	67.52	5544.0	80	4.37	219028	0	219028	0	0	24	8.66	104	9.96	356	47.62	174	33.77	6	3.00	0	0.00	3.95	30	4800	5520	26400	18720
36*	73.38	5541.6	80	12.43	228960	0	228960	0	0	24	8.66	100	10.18	356	47.64	171	33.52	9	4.50	0	0.00	4.70	33	4800	5640	26400	18576
36*	61.01	5535.6	80	56.14	208140	0	208140	0	0	24	8.67	102	10.08	356	47.69	171	33.56	8	4.00	0	0.00	4.55	38	4800	5580	26400	18576
36*	61.03	5534.4	80	40.22	208652	0	208652	0	0	24	8.67	104	9.97	356	47.70	173	33.65	4	2.00	0	0.00	4.60	33	4800	5520	26400	18624
36*	61.11	5538.8	80	11.53	208734	0	208734	0	0	24	8.67	110	10.22	356	47.66	172	33.45	12	6.00	0	0.00	6.25	36	4800	5660	26400	18528
36*	61.01	5534.4	80	32.18	209258	0	209258	0	0	24	8.67	104	9.97	356	47.70	173	33.65	6	3.00	0	0.00	5.20	37	4800	5520	26400	18624
36*	68.62	5544.0	80	4.51	205131	0	205131	0	0	24	8.66	104	9.96	356	47.62	174	33.77	4	2.00	0	0.00	5.05	37	4800	5520	26400	18720
36*	74.22	5534.8	80	55.47	238955	0	238955	0	0	24	8.67	106	10.15	356	47.70	172	33.48	9	4.50	0	0.00	5.30	34	4800	5620	26400	18528
36*	66.75	5542.0	80	32.09	215265	0	215265	0	0	24	8.66	102	10.36	356	47.64	170	33.35	11	5.50	0	0.00	4.90	36	4800	5740	26400	18480

Table D.64: Results of all runs made with NSF network case 3, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.29	5394.8	60	54.51	7310	0	0	0	0	20	7.41	410	38.00	162	23.36	165	31.23	20	2.56	0	0.00	4.80	32	4000	20500	12600	16848
1	60.17	5404.4	59	0.81	7352	0	0	0	0	20	7.40	410	37.93	162	23.31	166	31.35	17	2.18	0	0.00	4.25	31	4000	20500	12600	16944
1	60.29	5405.2	60	11.06	7373	0	0	0	0	20	7.40	406	37.85	162	23.31	165	31.44	20	2.56	0	0.00	4.05	32	4000	20460	12600	16992
1	60.17	5405.2	59	11.62	7345	0	0	0	0	20	7.40	406	37.85	162	23.31	165	31.44	16	2.05	0	0.00	3.65	31	4000	20460	12600	16992
1	60.31	5405.6	60	22.42	7335	0	0	0	0	20	7.40	408	38.03	162	23.31	164	31.26	18	2.31	0	0.00	3.35	19	4000	20560	12600	16896
1	60.17	5405.6	59	54.68	7278	0	0	0	0	20	7.40	408	38.03	162	23.31	164	31.26	19	2.44	0	0.00	3.95	28	4000	20560	12600	16896
1	60.29	5406.4	60	12.68	7372	0	0	0	0	20	7.40	404	37.96	162	23.31	163	31.34	15	1.92	0	0.00	4.40	33	4000	20520	12600	16944
1	60.18	5404.4	59	37.33	7316	0	0	0	0	20	7.40	410	37.93	162	23.31	166	31.35	20	2.56	0	0.00	4.30	34	4000	20500	12600	16944
1	60.29	5396.8	60	16.71	7325	0	0	0	0	20	7.41	404	38.02	162	23.35	162	31.22	23	2.95	0	0.00	4.15	35	4000	20520	12600	16848
1	60.18	5395.6	60	19.31	7337	0	0	0	0	20	7.41	406	37.92	162	23.35	164	31.31	18	2.31	0	0.00	4.90	34	4000	20460	12600	16896
12	60.18	5391.6	59	28.30	72588	0	0	0	0	20	7.40	402	37.78	162	23.31	164	31.26	18	2.31	0	0.00	3.85	28	4000	20420	12600	16896
12	60.29	5395.2	60	43.56	71637	0	0	0	0	20	7.41	404	37.71	162	23.34	165	31.47	18	2.31	0	0.00	5.00	36	4000	20360	12600	16992
12	60.18	5390.4	60	50.87	72978	0	0	0	0	18	6.66	406	37.85	164	23.87	163	31.35	19	2.44	0	0.00	4.75	36	3600	20460	12900	16944
12	60.31	5395.2	58	55.15	72725	0	0	0	0	20	7.40	404	37.67	162	23.31	165	31.44	18	2.31	0	0.00	3.85	31	4000	20360	12600	16992
12	60.18	5394.8	59	2.93	71645	0	0	0	0	20	7.40	410	37.93	162	23.31	165	31.17	24	3.08	0	0.00	3.90	36	4000	20500	12600	16848
12	60.20	5385.6	60	36.36	71750	0	0	0	0	20	7.40	404	37.66	162	23.31	164	31.25	23	2.95	0	0.00	4.10	28	4000	20360	12600	16896
12	60.33	5395.6	60	20.70	71761	0	0	0	0	20	7.41	406	37.88	162	23.33	164	31.28	16	2.05	0	0.00	3.30	27	4000	20460	12600	16896
12	60.18	5391.6	60	46.47	72424	0	0	0	0	20	7.41	402	37.81	162	23.33	164	31.29	18	2.31	0	0.00	4.15	22	4000	20420	12600	16896
12	60.33	5395.6	61	43.04	71427	0	0	0	0	20	7.41	406	37.89	162	23.33	164	31.29	20	2.56	0	0.00	3.60	36	4000	20460	12600	16896
12	60.20	5395.2	59	43.04	71853	0	0	0	0	20	7.41	404	37.73	162	23.35	165	31.49	16	2.05	0	0.00	4.05	35	4000	20360	12600	16992
36	66.28	5395.2	60	18.50	83226	0	0	0	0	20	7.40	404	37.66	162	23.31	165	31.43	17	2.18	0	0.00	4.10	36	4000	20360	12600	16992
36	66.08	5377.2	59	15.68	83952	0	0	0	0	20	7.39	402	37.71	162	23.27	161	30.93	24	3.08	0	0.00	3.75	36	4000	20420	12600	16752
36	69.09	5385.6	60	37.32	86683	0	0	0	0	20	7.39	404	37.64	162	23.29	164	31.23	16	2.05	0	0.00	3.55	22	4000	20360	12600	16896
36	75.63	5385.6	60	24.06	94908	0	0	0	0	20	7.40	404	37.66	162	23.31	164	31.26	20	2.56	0	0.00	5.00	25	4000	20360	12600	16896
36	77.08	5391.6	59	22.39	94250	0	0	0	0	20	7.39	402	37.74	162	23.29	164	31.23	17	2.18	0	0.00	3.25	21	4000	20420	12600	16896
36	75.35	5386.4	59	14.77	94386	0	0	0	0	20	7.40	408	38.04	162	23.31	162	30.91	22	2.82	0	0.00	4.25	35	4000	20560	12600	16704
36	68.41	5385.2	60	54.19	86818	0	0	0	0	20	7.39	402	37.45	162	23.29	165	31.41	20	2.56	0	0.00	5.40	36	4000	20260	12600	16992
36	72.15	5395.2	60	31.71	87835	0	0	0	0	20	7.41	404	37.70	162	23.33	165	31.46	19	2.44	0	0.00	3.75	32	4000	20360	12600	16992
36	65.86	5386.0	60	4.56	82322	0	0	0	0	20	7.39	406	37.79	162	23.27	163	31.03	16	2.05	0	0.00	3.45	36	4000	20460	12600	16800
36	69.06	5390.8	59	58.05	87938	0	0	0	0	20	7.40	406	37.86	162	23.31	165	31.17	17	2.18	0	0.00	4.10	27	4000	20460	12600	16848
36*	70.31	5394.8	61	6.05	87866	0	0	0	0	20	7.41	410	38.00	162	23.36	165	31.23	23	2.95	0	0.00	3.10	22	4000	20500	12600	16848
36*	60.87	5395.2	60	18.24	75895	0	0	0	0	20	7.41	404	37.74	162	23.35	165	31.49	20	2.56	0	0.00	4.20	28	4000	20360	12600	16992
36*	60.93	5385.6	60	33.91	77821	0	0	0	0	20	7.43	404	37.80	162	23.40	164	31.37	23	2.95	0	0.00	4.10	28	4000	20360	12600	16896
36*	60.98	5384.8	60	13.14	79613	0	0	0	0	20	7.43	408	37.88	162	23.40	165	31.29	20	2.56	0	0.00	4.00	29	4000	20400	12600	16848
36*	60.93	5385.6	60	39.08	79525	0	0	0	0	20	7.43	404	37.80	162	23.40	164	31.37	16	2.05	0	0.00	4.55	36	4000	20360	12600	16896
36*	61.07	5390.0	59	9.22	77466	0	0	0	0	18	6.68	404	37.77	164	23.93	164	31.61	21	2.69	0	0.00	3.60	22	3600	20360	12900	17040
36*	75.80	5394.8	60	47.91	79010	0	0	0	0	20	7.41	410	38.00	162	23.36	165	31.23	15	1.92	0	0.00	4.25	36	4000	20500	12600	16848
36*	73.60	5385.6	60	53.63	93053	0	0	0	0	20	7.43	404	37.80	162	23.40	164	31.37	16	2.05	0	0.00	3.55	22	4000	20360	12600	16896
36*	60.96	5395.2	60	44.38	78687	0	0	0	0	20	7.41	404	37.74	162	23.35	165	31.49	16	2.05	0	0.00	4.25	32	4000	20360	12600	16992
36*	60.95	5390.0	58	7.13	77925	0	0	0	0	20	7.42	402	37.59	162	23.38	167	31.61	18	2.31	0	0.00	3.00	28	4000	20260	12600	17040

Table D.65: Results of all runs made with NSF network case 4, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.20	6798.4	80	16.04	8566	0	3851	154	0	14	4.12	192	15.53	442	45.89	217	34.46	10	2.56	0	0.00	7.70	44	2800	10560	31200	23424
1	60.33	6806.0	80	35.65	8594	0	3880	166	0	16	4.70	196	15.34	440	45.40	221	34.56	8	2.05	0	0.00	7.55	44	3200	10440	30900	23520
1	60.18	6771.2	80	43.56	8664	0	3881	147	0	16	4.73	194	16.39	432	44.93	214	33.96	10	2.56	0	0.00	7.85	47	3200	11100	30420	22992
1	60.34	6819.6	80	32.73	8652	0	3851	159	0	16	4.69	184	15.37	440	45.31	219	34.63	9	2.31	0	0.00	7.80	45	3200	10480	30900	23616
1	60.20	6781.6	80	42.48	8658	0	3773	151	0	16	4.72	186	15.60	440	45.56	214	34.12	10	2.56	0	0.00	8.20	46	3200	10580	30900	23136
1	60.33	6802.8	80	31.08	8617	0	3863	156	0	16	4.70	196	15.58	440	45.42	216	34.29	14	3.59	0	0.00	7.95	47	3200	10600	30900	23328
1	60.18	6794.4	80	49.78	8628	0	3846	134	0	18	5.30	192	15.54	438	45.04	219	34.12	11	2.82	0	0.00	7.95	45	3600	10560	30600	23184
1	60.33	6780.0	80	39.05	8691	0	3853	150	0	18	5.31	192	15.58	438	45.13	216	33.98	13	3.33	0	0.00	7.60	42	3600	10560	30600	23040
1	60.20	6811.6	80	21.39	8598	0	3878	141	0	18	5.29	198	15.47	438	44.92	221	34.32	12	3.08	0	0.00	8.15	44	3600	10540	30600	23376
1	60.18	6816.0	80	9.31	8612	0	3871	140	0	16	4.69	190	15.82	440	45.33	217	34.15	20	5.13	0	0.00	7.45	43	3200	10780	30900	23280
12	60.20	6757.2	80	47.53	87511	0	38677	1521	0	16	4.70	184	15.39	440	45.39	214	33.77	11	2.82	0	0.00	7.80	49	3200	10480	30900	22992
12	60.36	6773.6	80	40.87	82864	0	36841	1482	0	16	4.69	194	15.40	440	45.32	217	33.93	11	2.82	0	0.00	8.20	43	3200	10500	30900	23136
12	60.20	6778.4	79	56.11	80925	0	35883	1435	0	18	5.30	192	15.30	438	45.02	219	34.11	10	2.56	0	0.00	8.05	44	3600	10400	30600	23184
12	60.36	6775.2	80	6.57	82225	0	36553	1451	0	18	5.28	192	15.50	438	44.91	217	33.74	12	3.08	0	0.00	8.10	49	3600	10560	30600	22992
12	60.20	6754.8	80	47.55	84738	0	37743	1520	0	18	5.29	194	15.44	438	44.99	217	33.59	13	3.33	0	0.00	8.15	43	3600	10500	30600	22848
12	60.33	6779.6	80	39.80	81522	0	36316	1424	0	16	4.72	192	15.58	440	45.58	217	34.13	10	2.56	0	0.00	7.30	44	3200	10560	30900	23136
12	60.22	6758.4	80	12.03	80042	0	35544	1464	0	18	5.30	196	15.36	438	45.02	218	33.75	10	2.56	0	0.00	7.90	44	3600	10440	30600	22944
12	60.34	6767.6	80	9.02	81694	0	36464	1429	0	16	4.69	196	15.31	440	45.31	217	33.93	10	2.56	0	0.00	10.10	47	3200	10440	30900	23136
12	60.22	6768.8	80	8.64	81884	0	36600	1439	0	18	5.32	192	15.36	438	45.21	218	34.11	10	2.56	0	0.00	7.05	50	3600	10400	30600	23088
12	60.33	6786.8	79	20.69	83739	0	37199	1455	0	18	5.30	186	15.57	438	45.03	218	33.98	14	3.59	0	0.00	8.45	45	3600	10580	30600	23088
36	75.10	6770.8	80	20.95	107541	0	47947	1897	0	16	4.68	188	15.39	440	45.20	215	33.77	13	3.33	0	0.00	8.10	45	3200	10520	30900	23088
36	68.06	6787.2	80	1.47	99653	0	44204	1756	0	16	4.69	198	15.45	440	45.30	218	34.06	13	3.33	0	0.00	7.85	48	3200	10540	30900	23232
36	77.14	6787.2	80	52.63	109007	0	48705	1851	0	18	5.27	196	15.29	438	44.82	221	34.03	9	2.31	0	0.00	8.75	48	3600	10440	30600	23232
36	68.41	6784.0	80	30.55	97079	0	43336	1716	0	16	4.70	190	15.37	440	45.40	217	34.21	10	2.56	0	0.00	7.05	46	3200	10460	30900	23280
36	76.64	6780.0	80	22.29	111652	0	49886	1898	0	18	5.29	192	15.51	438	44.95	219	33.84	8	2.05	0	0.00	7.90	50	3600	10560	30600	23040
36	75.52	6774.4	80	3.03	107001	0	47874	1895	0	16	4.70	190	15.37	440	45.40	216	34.06	13	3.33	0	0.00	7.65	51	3200	10460	30900	23184
36	69.01	6782.0	80	58.10	101470	0	45120	1820	0	16	4.70	196	15.34	440	45.39	217	34.20	9	2.31	0	0.00	7.75	47	3200	10440	30900	23280
36	67.27	6771.2	80	51.82	96791	0	43188	1690	0	16	4.69	194	16.27	432	44.59	214	33.70	10	2.56	0	0.00	7.85	47	3200	11100	30420	22992
36	68.84	6773.2	80	3.25	100793	0	45032	1770	0	16	4.72	192	15.33	440	45.55	218	34.25	11	2.82	0	0.00	7.50	42	3200	10400	30900	23232
36	76.13	6780.4	80	48.25	109774	0	48809	1916	0	16	4.68	188	15.39	440	45.20	213	33.92	10	2.56	0	0.00	8.35	48	3200	10520	30900	23184
36*	61.11	6780.4	80	54.15	83234	0	36789	1556	0	16	4.72	188	15.52	440	45.57	216	34.19	11	2.82	0	0.00	7.90	42	3200	10520	30900	23184
36*	66.85	6761.2	80	19.20	93138	0	41353	1656	0	18	5.32	194	15.77	438	45.26	216	33.65	15	3.85	0	0.00	8.20	45	3600	10660	30600	22752
36*	61.12	6779.6	78	51.70	75153	0	33385	1380	0	18	5.31	190	15.43	438	45.14	217	34.13	10	2.56	0	0.00	8.30	45	3600	10460	30600	23136
36*	60.92	6788.8	80	34.40	88556	0	39498	1623	0	16	4.71	190	15.41	440	45.52	216	34.36	11	2.82	0	0.00	8.10	45	3200	10460	30900	23328
36*	67.03	6767.6	80	8.92	85718	0	38169	1503	0	16	4.73	196	15.43	440	45.66	217	34.19	10	2.56	0	0.00	10.10	47	3200	10440	30900	23136
36*	61.04	6783.6	80	23.15	84805	0	37994	1453	0	16	4.72	196	15.63	440	45.55	217	34.11	12	3.08	0	0.00	8.05	49	3200	10600	30900	23136
36*	74.77	6782.4	80	39.30	92844	0	41278	1643	0	16	4.72	198	15.54	440	45.56	219	34.18	17	4.36	0	0.00	6.55	43	3200	10540	30900	23184
36*	67.86	6774.0	80	13.07	93891	0	41834	1648	0	18	5.31	194	15.50	438	45.17	219	34.01	14	3.59	0	0.00	7.85	47	3600	10500	30600	23040
36*	61.06	6790.0	80	52.62	87334	0	39017	1622	0	12	3.53	200	15.43	444	46.39	215	34.64	13	3.33	0	0.00	6.55	41	2400	10480	31500	23520
36*	61.28	6766.4	80	27.52	84968	0	37914	1508	0	16	4.73	198	15.34	440	45.67	219	34.26	8	2.05	0	0.00	7.60	44	3200	10380	30900	23184

Table D.66: Results of all runs made with NSF network case 5, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.36	7350.4	78	34.98	8114	0	1631	0	0	28	7.62	136	9.90	466	47.34	239	35.13	18	6.92	0	0.00	5.85	33	5600	7280	34800	25824
1	60.20	7368.8	79	30.93	8092	0	1677	0	0	24	6.51	136	9.88	470	48.04	240	35.57	14	5.38	0	0.00	5.35	26	4800	7280	35400	26208
1	60.34	7358.0	80	1.62	8032	0	1625	0	0	24	6.52	138	9.81	470	48.11	241	35.55	14	5.38	0	0.00	5.80	26	4800	7220	35400	26160
1	60.20	7359.6	79	18.81	8090	0	1682	0	0	28	7.61	134	9.76	466	47.29	241	35.35	14	5.38	0	0.00	5.45	29	5600	7180	34800	26016
1	60.34	7362.0	79	53.99	8069	0	1632	0	0	24	6.52	142	9.86	470	48.08	241	35.53	16	6.15	0	0.00	5.40	33	4800	7260	35400	26160
1	60.20	7362.0	80	51.21	8069	0	1665	0	0	24	6.52	142	9.86	470	48.08	241	35.53	16	6.15	0	0.00	5.15	29	4800	7260	35400	26160
1	60.33	7350.4	79	20.40	8099	0	1661	0	0	28	7.62	136	9.90	466	47.34	239	35.13	12	4.62	0	0.00	5.40	24	5600	7280	34800	25824
1	60.20	7372.4	79	40.89	8039	0	1703	0	0	28	7.60	142	9.85	466	47.20	243	35.35	15	5.77	0	0.00	5.85	36	5600	7260	34800	26064
1	60.37	7359.6	80	14.35	8084	0	1628	0	0	28	7.61	142	10.08	466	47.29	240	35.02	18	6.92	0	0.00	6.05	30	5600	7420	34800	25776
1	60.20	7344.4	79	22.43	8029	0	1672	0	0	28	7.62	138	9.83	466	47.38	239	35.16	15	5.77	0	0.00	5.70	23	5600	7220	34800	25824
12	60.20	7349.2	80	5.13	77393	0	16036	0	0	28	7.61	138	9.81	466	47.26	241	35.14	14	5.38	0	0.00	5.95	25	5600	7220	34800	25872
12	60.34	7350.0	79	59.55	79195	0	16319	0	0	28	7.61	134	9.76	466	47.29	240	35.22	12	4.62	0	0.00	5.80	24	5600	7180	34800	25920
12	60.20	7350.4	79	49.47	79176	0	16209	0	0	28	7.61	136	9.89	466	47.30	239	35.10	15	5.77	0	0.00	5.50	26	5600	7280	34800	25824
12	60.36	7356.4	80	47.86	79020	0	16166	0	0	28	7.60	134	9.97	466	47.25	239	35.06	18	6.92	0	0.00	5.95	32	5600	7340	34800	25824
12	60.20	7350.4	78	46.66	79405	0	16190	0	0	28	7.60	136	9.88	466	47.23	239	35.05	15	5.77	0	0.00	6.00	36	5600	7280	34800	25824
12	60.36	7336.8	79	35.77	76738	0	15876	0	0	28	7.61	132	9.84	466	47.32	238	34.98	14	5.38	0	0.00	6.40	29	5600	7240	34800	25728
12	60.22	7350.4	79	28.36	75634	0	15521	0	0	28	7.59	136	9.87	466	47.19	239	35.02	12	4.62	0	0.00	7.05	31	5600	7280	34800	25824
12	60.34	7346.4	79	39.52	75479	0	15481	0	0	28	7.62	132	9.85	466	47.34	239	35.13	15	5.77	0	0.00	5.65	26	5600	7240	34800	25824
12	60.36	7336.8	77	1.44	78529	0	16201	0	0	28	7.61	132	9.83	466	47.26	238	34.94	14	5.38	0	0.00	6.00	35	5600	7240	34800	25728
12	60.20	7331.2	78	38.31	76497	0	15682	0	0	28	7.60	136	9.87	466	47.20	237	34.77	16	6.15	0	0.00	6.65	34	5600	7280	34800	25632
36	74.21	7349.2	79	1.64	99542	0	20476	0	0	28	7.60	138	9.80	466	47.23	241	35.12	16	6.15	0	0.00	5.95	28	5600	7220	34800	25872
36	74.68	7339.6	80	44.18	101329	0	20896	0	0	28	7.61	138	9.81	466	47.26	240	35.01	12	4.62	0	0.00	6.90	30	5600	7220	34800	25776
36	66.52	7340.0	78	31.96	91306	0	18670	0	0	28	7.59	140	9.92	466	47.18	239	34.82	16	6.15	0	0.00	5.60	25	5600	7320	34800	25680
36	66.21	7349.6	78	22.31	90730	0	18545	0	0	24	6.51	136	9.88	470	48.04	238	35.31	16	6.15	0	0.00	6.45	35	4800	7280	35400	26016
36	68.48	7354.8	80	55.43	91068	0	18758	0	0	28	7.60	134	9.75	466	47.26	239	35.26	13	5.00	0	0.00	5.90	35	5600	7180	34800	25968
36	76.25	7343.6	79	11.76	101566	0	20608	0	0	28	7.60	142	9.86	466	47.24	240	34.99	16	6.15	0	0.00	6.00	35	5600	7260	34800	25776
36	76.81	7340.8	79	30.94	103378	0	21276	0	0	28	7.60	136	9.88	466	47.25	238	34.93	15	5.77	0	0.00	5.85	24	5600	7280	34800	25728
36	67.92	7349.6	80	10.72	91333	0	18731	0	0	28	7.61	140	9.95	466	47.29	240	35.03	15	5.77	0	0.00	5.55	28	5600	7320	34800	25776
36	67.06	7350.0	79	34.99	91092	0	18769	0	0	28	7.61	134	9.76	466	47.31	240	35.23	13	5.00	0	0.00	5.75	36	5600	7180	34800	25920
36	66.21	7355.2	80	30.79	90949	0	18845	0	0	28	7.60	136	9.89	466	47.26	241	35.13	16	6.15	0	0.00	5.10	28	5600	7280	34800	25872
36*	61.03	7344.4	79	28.07	81130	0	16813	0	0	28	7.62	138	9.83	466	47.38	239	35.16	15	5.77	0	0.00	5.70	23	5600	7220	34800	25824
36*	71.93	7350.0	79	59.73	87103	0	17886	0	0	28	7.62	134	9.77	466	47.35	240	35.27	12	4.62	0	0.00	5.80	24	5600	7180	34800	25920
36*	73.52	7344.8	79	49.36	94335	0	19348	0	0	28	7.62	140	9.97	466	47.38	238	35.03	17	6.54	0	0.00	6.00	37	5600	7320	34800	25728
36*	60.98	7343.2	79	21.93	83796	0	17230	0	0	28	7.63	140	9.75	466	47.39	241	35.23	15	5.77	0	0.00	6.15	30	5600	7160	34800	25872
36*	61.11	7354.0	78	45.13	78688	0	16124	0	0	28	7.61	138	9.82	466	47.32	240	35.25	14	5.38	0	0.00	5.95	33	5600	7220	34800	25920
36*	69.23	7340.8	78	30.25	94745	0	19475	0	0	28	7.63	136	9.92	466	47.41	238	35.05	16	6.15	0	0.00	5.90	35	5600	7280	34800	25728
36*	72.18	7343.6	79	43.79	83198	0	17024	0	0	28	7.63	142	9.89	466	47.39	240	35.10	13	5.00	0	0.00	5.60	27	5600	7260	34800	25776
36*	73.83	7344.8	79	43.65	90079	0	18467	0	0	28	7.62	140	9.97	466	47.38	238	35.03	16	6.15	0	0.00	5.65	33	5600	7320	34800	25728
36*	73.32	7344.0	79	14.84	94708	0	19451	0	0	28	7.63	136	9.70	466	47.39	240	35.29	13	5.00	0	0.00	4.85	29	5600	7120	34800	25920
36*	67.63	7349.6	78	20.08	83369	0	17250	0	0	24	6.53	136	9.91	470	48.17	238	35.40	16	6.15	0	0.00	6.45	35	4800	7280	35400	26016

Table D.67: Results of all runs made with NSF network case 6, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.23	7822.8	80	55.72	2424	0	2424	463	0	14	3.58	508	34.92	224	23.39	255	38.10	35	3.45	0	0.00	5.15	40	2800	27320	18300	29808
1	60.40	7886.4	80	52.43	2390	0	2390	411	0	14	3.55	498	34.41	224	23.20	259	38.83	28	2.76	0	0.00	4.65	34	2800	27140	18300	30624
1	60.23	7864.8	80	14.70	2395	0	2395	452	0	16	4.07	500	34.84	222	22.89	256	38.21	38	3.75	0	0.00	6.10	40	3200	27400	18000	30048
1	60.39	7910.0	80	29.42	2373	0	2373	410	0	16	4.05	502	34.36	222	22.76	260	38.84	25	2.47	0	0.00	4.95	45	3200	27180	18000	30720
1	60.23	7880.4	80	52.46	2407	0	2407	435	0	16	4.06	498	34.85	222	22.84	257	38.25	30	2.96	0	0.00	6.90	43	3200	27460	18000	30144
1	60.40	7848.4	80	23.70	2379	0	2379	410	0	16	4.08	498	34.58	222	22.93	257	38.41	32	3.16	0	0.00	4.95	32	3200	27140	18000	30144
1	60.22	7836.0	80	38.16	2427	0	2427	450	0	16	4.08	500	34.35	222	22.97	255	38.59	30	2.96	0	0.00	3.95	26	3200	26920	18000	30240
1	60.37	7867.2	80	28.41	2334	0	2334	398	0	16	4.07	504	34.68	222	22.88	259	38.38	28	2.76	0	0.00	4.45	23	3200	27280	18000	30192
1	60.23	7839.6	80	0.36	2385	0	2385	425	0	20	5.10	498	34.62	218	22.20	263	38.08	32	3.16	0	0.00	3.65	41	4000	27140	17400	29856
1	60.25	7822.4	80	26.50	2446	0	2446	460	0	22	5.62	498	34.90	216	21.86	254	37.62	28	2.76	0	0.00	6.60	43	4400	27300	17100	29424
12	60.26	7842.4	80	42.03	24710	0	24710	4321	0	20	5.09	496	34.82	218	22.14	249	37.75	39	3.85	0	0.00	5.65	33	4000	27360	17400	29664
12	60.43	7803.2	80	19.19	23819	0	23819	4202	0	14	3.56	506	34.62	224	23.28	251	37.79	32	3.16	0	0.00	4.55	25	2800	27220	18300	29712
12	60.29	7799.2	80	48.05	22976	0	22976	4174	0	16	4.06	500	34.35	222	22.83	251	37.69	30	2.96	0	0.00	5.00	29	3200	27080	18000	29712
12	60.40	7832.0	80	36.04	23967	0	23967	4309	0	16	4.08	496	34.24	222	22.93	258	38.52	23	2.27	0	0.00	4.50	33	3200	26880	18000	30240
12	60.31	7857.6	80	20.36	23809	0	23809	4406	0	14	3.56	506	34.85	224	23.29	258	38.30	35	3.45	0	0.00	4.00	33	2800	27380	18300	30096
12	60.43	7830.4	80	58.91	24019	0	24019	4443	0	14	3.55	498	34.64	224	23.22	244	37.94	35	3.45	0	0.00	4.20	41	2800	27300	18300	29904
12	60.26	7839.6	80	17.28	23756	0	23756	4269	0	22	5.58	496	34.92	216	21.70	246	37.27	34	3.35	0	0.00	5.30	32	4400	27520	17100	29376
12	60.43	7820.0	80	18.89	23991	0	23991	4301	0	16	4.08	500	34.70	222	22.93	253	37.91	33	3.25	0	0.00	4.15	43	3200	27240	18000	29760
12	60.28	7807.2	80	6.37	24472	0	24472	4411	0	16	4.08	500	34.34	222	22.96	258	38.21	29	2.86	0	0.00	4.50	33	3200	26920	18000	29952
12	60.40	7818.8	80	55.74	23601	0	23601	4243	0	16	4.07	502	34.55	222	22.88	258	37.89	35	3.45	0	0.00	6.45	44	3200	27180	18000	29808
36	73.46	7800.0	80	12.11	30496	0	30496	5540	0	16	4.05	496	34.25	222	22.80	256	37.69	24	2.37	0	0.00	4.25	45	3200	27040	18000	29760
36	79.06	7818.4	80	27.92	33041	0	33041	6020	0	16	4.03	500	34.10	222	22.66	253	37.65	26	2.56	0	0.00	4.60	32	3200	27080	18000	29904
36	65.58	7828.8	80	20.02	27579	0	27579	4998	0	22	5.55	490	34.34	216	21.57	257	37.30	34	3.35	0	0.00	4.70	41	4400	27220	17100	29568
36	74.02	7826.8	80	46.39	30345	0	30345	5646	0	16	4.07	502	34.99	222	22.90	257	37.62	36	3.55	0	0.00	3.45	25	3200	27500	18000	29568
36	77.36	7825.2	80	37.99	31644	0	31644	5798	0	18	4.56	500	34.51	220	22.42	251	37.64	40	3.94	0	0.00	4.90	39	3600	27240	17700	29712
36	70.70	7840.4	80	53.15	29595	0	29595	5333	0	20	5.09	502	34.78	218	22.13	258	37.73	39	3.85	0	0.00	5.00	29	4000	27340	17400	29664
36	73.80	7836.0	79	33.06	30440	0	30440	5467	0	16	4.05	492	34.35	222	22.77	248	37.94	34	3.35	0	0.00	4.85	44	3200	27160	18000	30000
36	78.06	7829.6	80	28.30	32052	0	32052	5731	0	24	6.07	484	34.26	214	21.26	259	37.47	31	3.06	0	0.00	5.40	38	4800	27080	16800	29616
36	67.24	7791.2	80	44.15	27785	0	27785	4992	0	14	3.55	494	34.31	224	23.17	248	37.62	30	2.96	0	0.00	3.10	25	2800	27100	18300	29712
36	66.69	7818.0	80	10.98	28253	0	28253	5210	0	24	6.07	490	34.24	214	21.26	252	37.36	30	2.96	0	0.00	5.35	37	4800	27060	16800	29520
36*	71.18	7834.8	80	49.08	29433	0	29433	5294	0	18	4.59	492	34.46	220	22.59	256	38.35	33	3.25	0	0.00	4.95	33	3600	27000	17700	30048
36*	61.42	7838.4	80	10.36	24824	0	24824	4370	0	16	4.08	488	34.80	222	22.96	253	38.15	33	3.25	0	0.00	3.90	26	3200	27280	18000	29904
36*	68.67	7806.8	80	53.55	26244	2	26244	4889	0	16	4.10	498	34.97	222	23.06	254	37.87	29	2.86	0	0.00	5.30	35	3200	27300	18000	29568
36*	61.20	7820.0	80	18.66	25872	0	25872	4699	0	16	4.09	500	34.83	222	23.02	253	38.06	33	3.25	0	0.00	4.15	43	3200	27240	18000	29760
36*	61.03	7807.2	80	5.48	24630	0	24630	4449	0	14	3.59	510	34.92	224	23.44	248	38.06	38	3.75	0	0.00	3.75	40	2800	27260	18300	29712
36*	60.98	7837.6	80	30.00	25007	0	25007	4559	0	14	3.57	502	34.68	224	23.35	255	38.40	32	3.16	0	0.00	3.85	37	2800	27180	18300	30096
36*	60.93	7818.4	80	26.82	25953	0	25953	4766	0	16	4.09	500	34.64	222	23.02	253	38.25	26	2.56	0	0.00	4.60	32	3200	27080	18000	29904
36*	61.07	7818.4	80	32.82	25500	0	25500	4583	0	20	5.12	496	34.99	218	22.26	254	37.63	36	3.55	0	0.00	5.35	42	4000	27360	17400	29424
36*	60.98	7830.0	80	22.79	25625	0	25625	4670	0	16	4.09	510	35.22	222	22.99	252	37.70	40	3.94	0	0.00	5.40	37	3200	27580	18000	29520
36*	61.07	7829.2	80	36.97	24660	0	24660	4372	0	14	3.58	500	34.79	224	23.37	252	38.26	28	2.76	0	0.00	6.00	31	2800	27240	18300	29952

Table D.68: Results of all runs made with NSF network case 7, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.47	8395.2	80	40.33	2371	0	2371	98	0	20	4.76	234	16.60	574	48.10	243	30.53	19	3.75	0	0.00	4.65	22	4000	13940	40380	25632
1	60.23	8402.4	80	16.99	2343	0	2343	94	0	20	4.76	230	16.16	574	48.06	246	31.02	19	3.75	0	0.00	3.30	23	4000	13580	40380	26064
1	60.42	8377.6	80	12.99	2360	0	2360	99	0	18	4.30	228	16.66	576	48.56	236	30.48	27	5.33	0	0.00	4.65	24	3600	13960	40680	25536
1	60.23	8407.6	80	56.88	2361	0	2361	114	0	20	4.76	240	16.56	574	48.03	246	30.66	24	4.73	0	0.00	3.10	21	4000	13920	40380	25776
1	60.40	8386.0	80	17.08	2391	0	2391	124	0	20	4.77	228	16.46	574	48.15	242	30.62	17	3.35	0	0.00	2.95	22	4000	13800	40380	25680
1	60.23	8405.6	80	20.56	2349	0	2349	101	0	18	4.28	232	16.66	576	48.40	240	30.67	26	5.13	0	0.00	3.05	26	3600	14000	40680	25776
1	60.40	8406.8	80	45.72	2394	0	2394	112	0	18	4.28	230	16.72	576	48.39	238	30.60	22	4.34	0	0.00	3.35	21	3600	14060	40680	25728
1	60.23	8402.8	80	11.40	2377	0	2377	114	0	20	4.76	224	16.57	574	48.06	238	30.62	20	3.94	0	0.00	3.45	19	4000	13920	40380	25728
1	60.40	8390.8	80	52.18	2389	0	2389	117	0	20	4.77	236	16.73	574	48.12	240	30.38	21	4.14	0	0.00	4.20	23	4000	14040	40380	25488
1	60.23	8366.4	80	37.33	2378	0	2378	90	0	18	4.30	228	16.49	576	48.62	238	30.58	16	3.16	0	0.00	4.45	21	3600	13800	40680	25584
12	60.26	8382.0	80	49.90	24194	0	24194	1073	0	20	4.76	224	16.38	574	48.07	245	30.57	18	3.55	0	0.00	2.40	17	4000	13760	40380	25680
12	60.43	8385.2	80	3.50	24019	0	24019	1099	0	20	4.76	240	16.18	574	48.04	247	30.78	16	3.16	0	0.00	2.85	19	4000	13600	40380	25872
12	60.28	8372.4	80	25.15	23256	0	23256	999	0	20	4.75	224	16.36	574	48.00	241	30.41	20	3.94	0	0.00	2.75	21	4000	13760	40380	25584
12	60.42	8365.6	80	9.72	23105	0	23105	1046	0	20	4.77	230	16.38	574	48.14	242	30.45	19	3.75	0	0.00	4.45	23	4000	13740	40380	25536
12	60.26	8372.0	80	45.30	24178	0	24178	1108	0	20	4.76	230	16.54	574	48.04	241	30.27	18	3.55	0	0.00	2.80	19	4000	13900	40380	25440
12	60.43	8368.0	80	15.87	23239	0	23239	1065	0	20	4.77	226	16.52	574	48.12	241	30.32	22	4.34	0	0.00	4.10	21	4000	13860	40380	25440
12	60.26	8379.6	80	22.90	23343	0	23343	1054	0	20	4.77	236	16.56	574	48.19	245	30.47	20	3.94	0	0.00	4.90	23	4000	13880	40380	25536
12	60.45	8352.4	80	15.59	24374	0	24374	1008	0	20	4.76	228	16.42	574	48.04	240	30.15	21	4.14	0	0.00	5.00	32	4000	13800	40380	25344
12	60.45	8389.2	80	31.78	23178	0	23178	1081	0	18	4.29	230	16.38	576	48.49	241	30.84	16	3.16	0	0.00	3.05	21	3600	13740	40680	25872
12	60.28	8380.8	80	21.57	24258	0	24258	1035	0	20	4.76	234	16.60	574	48.10	243	30.36	24	4.73	0	0.00	3.70	28	4000	13940	40380	25488
36	68.55	8366.0	80	18.77	27363	0	27363	1205	0	18	4.28	226	16.30	576	48.39	239	30.55	17	3.35	0	0.00	3.25	22	3600	13700	40680	25680
36	74.08	8370.4	80	9.00	30679	0	30679	1355	0	20	4.77	230	16.40	574	48.20	241	30.54	21	4.14	0	0.00	4.10	21	4000	13740	40380	25584
36	74.55	8379.2	80	54.90	30515	0	30515	1284	0	20	4.75	234	16.38	574	47.99	243	30.47	22	4.34	0	0.00	4.10	24	4000	13780	40380	25632
36	66.41	8378.8	80	56.49	26879	0	26879	1219	0	20	4.74	240	16.49	574	47.84	243	30.19	22	4.34	0	0.00	4.45	23	4000	13920	40380	25488
36	74.07	8366.8	80	5.58	31230	0	31230	1427	0	20	4.75	228	16.40	574	47.98	240	30.29	21	4.14	0	0.00	4.05	27	4000	13800	40380	25488
36	72.32	8359.2	80	48.10	29861	0	29861	1318	0	20	4.77	222	16.47	574	48.13	239	30.27	22	4.34	0	0.00	4.25	21	4000	13820	40380	25392
36	77.81	8375.6	80	10.28	32343	0	32343	1392	0	20	4.76	232	16.48	574	48.09	242	30.41	21	4.14	0	0.00	3.25	23	4000	13840	40380	25536
36	68.76	8375.6	80	39.06	28614	0	28614	1337	0	18	4.28	234	16.59	576	48.41	236	30.39	25	4.93	0	0.00	4.80	23	3600	13940	40680	25536
36	75.89	8364.8	80	54.34	31829	0	31829	1459	0	20	4.75	226	16.66	574	47.99	239	30.01	25	4.93	0	0.00	4.10	19	4000	14020	40380	25248
36	67.20	8366.4	80	42.42	27878	0	27878	1264	0	18	4.28	228	16.41	576	48.37	238	30.42	16	3.16	0	0.00	4.45	21	3600	13800	40680	25584
36*	68.17	8379.2	80	43.73	26116	0	26116	1156	0	20	4.77	226	16.73	574	48.19	242	30.30	22	4.34	0	0.00	4.65	24	4000	14020	40380	25392
36*	74.01	8380.4	80	58.16	27783	0	27783	1314	0	20	4.77	232	16.51	574	48.18	244	30.53	23	4.54	0	0.00	4.05	20	4000	13840	40380	25584
36*	61.37	8382.0	80	23.01	25910	0	25910	1163	0	20	4.77	232	16.70	574	48.17	241	30.35	19	3.75	0	0.00	4.35	26	4000	14000	40380	25440
36*	67.38	8352.4	80	58.87	26013	0	26013	1157	0	20	4.79	228	16.52	574	48.35	240	30.34	21	4.14	0	0.00	5.00	32	4000	13800	40380	25344
36*	61.09	8370.8	80	21.39	25553	0	25553	1184	0	20	4.78	232	16.53	574	48.24	243	30.45	22	4.34	0	0.00	4.60	23	4000	13840	40380	25488
36*	73.99	8366.0	80	37.13	28360	0	28360	1299	0	18	4.30	226	16.38	576	48.63	239	30.70	17	3.35	0	0.00	3.25	22	3600	13700	40680	25680
36*	73.15	8370.4	80	8.10	28147	0	28147	1310	0	20	4.78	230	16.42	574	48.24	241	30.56	21	4.14	0	0.00	4.10	21	4000	13740	40380	25584
36*	67.80	8378.0	80	35.51	26430	0	26430	1109	0	20	4.77	228	16.66	574	48.20	238	30.37	23	4.54	0	0.00	3.80	28	4000	13960	40380	25440
36*	61.21	8364.0	80	43.38	25056	0	25056	1061	0	20	4.78	222	16.52	574	48.28	238	30.42	22	4.34	0	0.00	3.20	27	4000	13820	40380	25440
36*	61.09	8366.8	80	42.59	24305	0	24305	1078	0	20	4.78	228	16.49	574	48.26	240	30.46	21	4.14	0	0.00	4.05	27	4000	13800	40380	25488

Table D.69: Results of all runs made with NSF network case 8, in 60 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	#10G	%10G	#40G	%40G	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	60.46	10249.6	80	40.20	1573	0	1573	690	0	26	5.07	216	17.19	532	40.45	286	38.03	28	8.28	0	0.00	1.45	9	5200	17620	41460	38976
1	60.25	10032.8	80	30.74	1590	0	1590	698	0	26	5.18	200	16.15	540	41.09	290	37.37	25	7.40	0	0.00	2.45	19	5200	16200	41220	37488
1	60.46	10215.2	80	42.28	1601	0	1601	717	0	22	4.31	218	16.60	540	41.23	282	37.07	28	8.28	0	0.00	1.75	8	4400	16960	42120	37872
1	60.25	10176.8	80	40.03	1634	0	1634	746	0	20	3.93	200	15.23	556	42.51	290	37.54	26	7.69	1	0.39	2.90	27	4000	15500	43260	38208
1	60.45	10306.8	80	57.33	1596	0	1596	706	0	24	4.66	202	15.87	544	40.92	290	37.77	31	9.17	0	0.00	1.85	17	4800	16360	42180	38928
1	60.26	10211.2	80	8.10	1685	0	1685	786	0	22	4.31	190	14.57	558	42.31	295	38.03	28	8.28	0	0.00	1.90	18	4400	14880	43200	38832
1	60.43	10209.2	80	49.55	1668	0	1668	741	0	20	3.92	204	15.59	552	42.14	287	37.57	25	7.40	0	0.00	1.55	9	4000	15920	43020	38352
1	60.26	10326.4	80	51.51	1674	0	1674	757	0	24	4.65	198	15.38	558	42.18	288	37.79	27	7.99	1	0.39	1.40	17	4800	15880	43560	39024
1	60.45	10112.4	80	45.96	1675	0	1675	751	0	22	4.35	222	16.87	534	41.30	283	36.69	23	6.80	0	0.00	1.95	11	4400	17060	41760	37104
1	60.50	10255.6	80	3.65	1597	0	1597	714	0	26	5.07	202	16.01	538	40.60	290	37.54	25	7.40	0	0.00	2.20	9	5200	16420	41640	38496
12	60.39	10064.0	80	43.49	17463	0	17463	7942	0	22	4.37	204	16.26	540	41.85	277	36.73	28	8.28	0	0.00	2.55	13	4400	16360	42120	36960
12	60.39	10123.2	80	41.31	17281	0	17281	7808	0	22	4.33	202	15.79	548	41.95	283	36.82	21	6.21	0	0.00	1.75	9	4400	16040	42600	37392
12	60.56	10140.8	80	21.86	17460	0	17460	7882	0	22	4.30	188	14.83	556	42.14	289	37.14	30	8.88	0	0.00	3.30	29	4400	15160	43080	37968
12	60.40	10063.2	80	18.00	17805	0	17805	8047	0	26	5.14	194	15.67	550	41.91	282	36.04	31	9.17	0	0.00	2.05	19	5200	15840	42360	36432
12	60.53	10088.8	80	15.69	16880	0	16880	7627	0	20	3.89	210	16.20	546	41.49	275	35.76	26	7.69	0	0.00	3.25	13	4000	16660	42660	36768
12	60.55	10185.2	80	32.29	15869	0	15869	7285	0	22	4.23	198	15.34	548	41.00	283	36.68	26	7.69	0	0.00	1.55	9	4400	15940	42600	38112
12	60.42	10250.4	80	40.30	16809	0	16809	7293	0	22	4.25	196	15.01	558	41.69	292	37.19	30	8.88	0	0.00	1.70	16	4400	15560	43200	38544
12	61.56	10226.0	80	53.79	15859	0	15859	7314	0	20	3.86	202	15.35	554	41.58	286	37.01	36	10.65	0	0.00	1.85	13	4000	15920	43140	38400
12	61.39	10305.2	80	22.45	15939	0	15939	7356	0	26	4.99	212	16.35	536	40.17	289	37.25	29	8.58	0	0.00	4.30	27	5200	17040	41880	38832
12	6.64	10198.8	80	55.01	16249	0	16249	8272	0	24	4.62	208	16.23	534	40.06	280	36.58	20	5.92	0	0.00	1.35	11	4800	16840	41580	37968
36	78.76	10108.4	80	11.33	22765	0	22765	10205	0	26	5.10	202	16.28	538	40.88	273	36.19	34	10.06	0	0.00	1.80	15	5200	16580	41640	36864
36	70.70	10087.6	80	40.93	21257	0	21257	9515	0	22	4.26	190	14.92	554	41.56	279	36.08	27	7.99	0	0.00	2.70	13	4400	15420	42960	37296
36	76.21	10095.6	80	50.36	19965	0	19965	8932	0	22	4.36	194	15.00	556	42.67	283	37.18	26	7.69	0	0.00	2.35	11	4400	15140	43080	37536
36	76.02	10118.0	80	32.93	19682	0	19682	7140	0	20	3.84	202	15.84	550	41.14	274	35.44	30	8.88	0	0.00	1.55	11	4000	16520	42900	36960
36	75.53	10218.4	80	59.98	21670	0	21670	8616	0	26	5.09	212	16.25	540	40.87	280	37.02	27	7.99	0	0.00	2.55	11	5200	16600	41760	37824
36	78.58	10146.0	80	13.78	20744	0	20744	9483	0	26	5.13	190	14.67	558	42.40	289	38.56	26	7.69	0	0.00	1.70	12	5200	14880	43020	39120
36	76.55	10170.4	80	38.44	18782	0	18782	7143	0	30	5.74	194	15.73	534	38.74	298	36.87	29	8.58	0	0.00	2.85	14	6000	16440	40500	38544
36	77.36	10106.4	80	47.78	19963	0	19963	8666	0	26	5.04	198	15.22	548	40.91	280	35.93	29	8.58	0	0.00	1.85	18	5200	15720	42240	37104
36	77.02	10218.4	80	36.29	18849	0	18849	7272	0	26	4.93	212	15.75	540	39.62	280	35.88	27	7.99	0	0.00	2.55	11	5200	16600	41760	37824
36	76.26	10169.2	80	42.26	19633	0	19633	8131	0	24	4.71	208	15.99	548	41.66	280	36.72	30	8.88	0	0.00	1.50	18	4800	16280	42420	37392
36*	61.15	10128.0	80	27.46	17441	0	17441	7932	0	26	5.13	204	15.88	548	41.71	283	36.49	28	8.28	0	0.00	3.50	34	5200	16080	42240	36960
36*	61.39	10161.6	80	35.43	17269	0	17269	7842	0	26	5.12	216	16.53	540	41.10	281	36.47	29	8.58	0	0.00	2.25	9	5200	16800	41760	37056
36*	61.20	10088.8	80	5.10	18285	0	18285	8190	0	20	3.96	210	16.51	546	42.28	275	36.44	26	7.69	0	0.00	3.25	13	4000	16660	42660	36768
36*	68.44	10135.2	80	56.52	17718	0	17718	8006	0	22	4.34	198	15.35	554	42.39	281	37.13	29	8.58	0	0.00	1.15	8	4400	15560	42960	37632
36*	61.00	10088.8	80	28.53	18579	0	18579	8471	0	20	3.96	210	16.51	546	42.28	275	36.44	26	7.69	0	0.00	3.25	13	4000	16660	42660	36768
36*	61.40	10022.4	80	30.26	18008	0	18008	8078	0	22	4.39	204	15.29	556	42.98	275	36.54	25	7.40	0	0.00	2.70	11	4400	15320	43080	36624
36*	61.34	10135.2	80	55.57	18215	0	18215	8219	0	22	4.34	198	15.35	554	42.39	281	37.13	29	8.58	0	0.00	1.15	8	4400	15560	42960	37632
36*	61.21	9996.0	80	50.36	19965	0	19965	8932	0	28	5.60	200	15.07	548	41.72	292	37.70	20	5.92	0	0.00	1.75	12	5600	15060	41700	37680
36*	61.17	10131.2	80	45.23	17140	0	17140	8400	0	22	4.34	210	15.91	544	41.81	284	37.14	20	5.92	0	0.00	3.50	21	4400	16120	42360	37632
36*	61.45	10146.0	80	39.88	18214	0	18214	8476	0	26	5.13	190	14.67	558	42.40	289	38.56	26	7.69	0	0.00	1.70	12	5200	14880	43020	39120

Table D.70: Results of all runs made with NSF network case 9, in 60 seconds.

D.8 NSF, Given 300 Seconds

Symbol	Name
$\#T$	Number of Threads
t_E	Time of Execution
C	Best Cost Solution found
CA	Highest Channel Assigned
t_{sol}	Found Solution Time
$\#i$	Number of Iterations
$\#IS$	Number of Invalid Solutions
$\#G_U$	Number of Greedy Solutions Unfeasible
$\#LS_U$	Number of Local Search Solutions Unfeasible
UD	Unfeasible Degree
$\#IM$	Number of Invert Multiplex used
C_{IM}	Cost % of Invert Multiplex
$\#MX$	Number of Muxponders placed
C_{MX}	Cost % of Muxponders
$\#TX$	Number of Transponders placed
C_{TX}	Cost % of Transponders
$\#3R$	Number of $3R$ regenerators placed
C_{3R}	Cost % of $3R$ regenerators
#10	Number of Multi-Hop Grooming of $10Gb/s$
%10	Traffic % of Multi-Hop Grooming of $10Gb/s$
#40	Number of Multi-hop Grooming of $40Gb/s$
%40	Traffic % of Multi-hop Grooming of $40Gb/s$
$\bar{m}F$	Average Fragmentation at Channel Assigned
MF	Max Fragmentation at Channel Assigned
C_{IM}	Cost of Invert Multiplexers
C_{MX}	Cost of Multiplexers
C_{TX}	Cost of Transponders
C_{3R}	Cost of $3R$ regenerators

Table D.71: Header symbols and their description.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.21	4440.4	59	39.56	126719	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	8	1.33	0	0.00	4.45	29	2800	15480	9900	16224
1	300.21	4440.4	59	1.09	126793	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	6	1.00	0	0.00	4.05	28	2800	15480	9900	16224
1	300.11	4440.4	59	36.30	127293	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	9	1.50	0	0.00	5.10	22	2800	15480	9900	16224
1	300.21	4440.4	59	37.64	127526	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	6	1.00	0	0.00	4.20	26	2800	15480	9900	16224
1	300.13	4440.4	59	42.53	127048	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	7	1.17	0	0.00	3.85	29	2800	15480	9900	16224
1	300.21	4440.4	59	4.18	127553	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	7	1.17	0	0.00	4.75	29	2800	15480	9900	16224
1	300.16	4440.4	59	5.32	126596	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	8	1.33	0	0.00	4.45	29	2800	15480	9900	16224
1	300.11	4440.4	59	10.62	127026	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	8	1.33	0	0.00	4.70	29	2800	15480	9900	16224
1	300.21	4440.4	59	30.95	127182	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	7	1.17	0	0.00	4.75	29	2800	15480	9900	16224
1	300.11	4440.4	59	2.59	127046	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	8	1.33	0	0.00	3.90	29	2800	15480	9900	16224
12	300.14	4440.4	59	0.41	1177625	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	7	1.17	0	0.00	4.10	29	2800	15480	9900	16224
12	300.21	4440.4	59	4.17	1121105	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	8	1.33	0	0.00	5.10	26	2800	15480	9900	16224
12	300.22	4440.4	59	2.04	1248717	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	10	1.67	0	0.00	4.90	26	2800	15480	9900	16224
12	300.14	4438.8	59	285.00	1194687	0	0	0	0	14	6.31	308	35.04	126	22.30	159	36.32	12	2.00	0	0.00	4.95	29	2800	15560	9900	16128
12	300.24	4440.4	59	0.17	1225621	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	6	1.00	0	0.00	3.70	25	2800	15480	9900	16224
12	300.13	4438.8	59	53.06	1233162	0	0	0	0	14	6.31	308	35.04	126	22.30	159	36.32	12	2.00	0	0.00	4.80	29	2800	15560	9900	16128
12	300.22	4440.4	59	0.11	1286791	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	8	1.33	0	0.00	4.35	25	2800	15480	9900	16224
12	300.14	4440.4	59	1.72	1248138	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	6	1.00	0	0.00	4.75	29	2800	15480	9900	16224
12	300.13	4440.4	59	4.01	1243187	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	8	1.33	0	0.00	4.50	25	2800	15480	9900	16224
12	300.22	4440.4	59	0.05	1202823	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	7	1.17	0	0.00	5.25	29	2800	15480	9900	16224
36	313.09	4438.8	59	154.69	1372455	0	0	0	0	14	6.31	308	35.04	126	22.30	159	36.32	11	1.83	0	0.00	4.80	29	2800	15560	9900	16128
36	318.10	4440.4	59	1.90	1384725	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	8	1.33	0	0.00	4.80	29	2800	15480	9900	16224
36	306.42	4440.4	59	0.90	1352081	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	7	1.17	0	0.00	5.20	30	2800	15480	9900	16224
36	306.09	4440.4	59	1.79	1363541	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	7	1.17	0	0.00	4.90	29	2800	15480	9900	16224
36	310.95	4438.8	60	276.54	1378069	0	0	0	0	14	6.31	308	35.04	126	22.30	159	36.32	13	2.17	0	0.00	4.00	25	2800	15560	9900	16128
36	317.23	4438.8	59	175.05	1379843	0	0	0	0	14	6.31	308	35.04	126	22.30	159	36.32	12	2.00	0	0.00	4.70	27	2800	15560	9900	16128
36	307.74	4440.4	59	0.45	1337179	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	7	1.17	0	0.00	4.00	30	2800	15480	9900	16224
36	316.87	4440.4	59	0.16	1399740	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	6	1.00	0	0.00	3.70	25	2800	15480	9900	16224
36	316.43	4438.8	60	137.92	1355277	0	0	0	0	14	6.31	308	35.04	126	22.30	159	36.32	13	2.17	0	0.00	3.95	22	2800	15560	9900	16128
36	308.94	4438.8	60	69.59	1367714	0	0	0	0	14	6.31	308	35.04	126	22.30	159	36.32	12	2.00	0	0.00	4.05	26	2800	15560	9900	16128
36*	315.65	4440.4	59	0.92	1393096	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	6	1.00	0	0.00	4.20	29	2800	15480	9900	16224
36*	300.99	4440.4	59	0.02	1314395	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	8	1.33	0	0.00	4.55	29	2800	15480	9900	16224
36*	313.97	4440.4	59	0.36	1281707	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	7	1.17	0	0.00	4.60	29	2800	15480	9900	16224
36*	307.20	4440.4	59	2.84	1348085	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	8	1.33	0	0.00	4.40	25	2800	15480	9900	16224
36*	300.88	4440.4	59	0.14	1316073	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	8	1.33	0	0.00	4.15	30	2800	15480	9900	16224
36*	313.73	4438.8	58	282.36	1338887	0	0	0	0	14	6.31	308	35.05	126	22.30	159	36.33	12	2.00	0	0.00	4.15	25	2800	15560	9900	16128
36*	310.07	4438.8	59	55.90	1328039	0	0	0	0	14	6.31	308	35.05	126	22.30	159	36.33	11	1.83	0	0.00	5.85	29	2800	15560	9900	16128
36*	312.36	4440.4	59	0.03	1347812	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	7	1.17	0	0.00	4.95	29	2800	15480	9900	16224
36*	312.97	4438.8	59	141.54	1309450	0	0	0	0	14	6.31	308	35.05	126	22.30	159	36.33	12	2.00	0	0.00	5.05	25	2800	15560	9900	16128
36*	314.51	4440.4	59	0.47	1321386	0	0	0	0	14	6.31	300	34.86	126	22.30	157	36.54	7	1.17	0	0.00	4.90	29	2800	15480	9900	16224

Table D.72: Results of all runs made with NSF network case 1, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.22	4892.4	62	55.88	94735	0	0	0	0	16	6.54	152	16.52	334	47.22	141	29.73	11	3.67	0	0.00	5.20	30	3200	8080	23100	14544
1	300.13	4892.0	63	18.78	94653	0	0	0	0	16	6.54	158	16.80	334	47.22	141	29.44	10	3.33	0	0.00	5.35	29	3200	8220	23100	14400
1	300.22	4892.4	61	33.74	94541	0	0	0	0	16	6.54	152	16.52	334	47.22	141	29.73	10	3.33	0	0.00	5.90	28	3200	8080	23100	14544
1	300.13	4887.6	61	222.57	94750	0	0	0	0	16	6.55	152	16.53	334	47.26	142	29.66	10	3.33	0	0.00	4.90	27	3200	8080	23100	14496
1	300.22	4892.8	64	175.42	94602	0	0	0	0	16	6.54	154	16.72	334	47.21	140	29.53	13	4.33	0	0.00	4.50	28	3200	8180	23100	14448
1	300.22	4892.4	60	157.19	94904	0	0	0	0	16	6.54	152	16.52	334	47.22	141	29.73	9	3.00	0	0.00	5.50	31	3200	8080	23100	14544
1	300.13	4891.6	65	20.72	94738	0	0	0	0	16	6.54	156	16.60	334	47.22	139	29.63	11	3.67	0	0.00	5.25	23	3200	8120	23100	14496
1	300.22	4882.8	62	292.53	94810	0	0	0	0	16	6.55	152	16.55	334	47.31	140	29.59	11	3.67	0	0.00	5.15	25	3200	8080	23100	14448
1	300.13	4892.4	62	109.76	94761	0	0	0	0	16	6.54	152	16.52	334	47.22	141	29.73	11	3.67	0	0.00	5.35	27	3200	8080	23100	14544
1	300.22	4887.6	61	106.45	94684	0	0	0	0	16	6.55	152	16.53	334	47.26	142	29.66	10	3.33	0	0.00	4.90	29	3200	8080	23100	14496
12	300.13	4882.8	62	251.52	963995	0	0	0	0	16	6.54	152	16.52	334	47.22	140	29.53	11	3.67	0	0.00	5.05	31	3200	8080	23100	14448
12	300.25	4882.8	62	249.23	937919	0	0	0	0	16	6.54	152	16.51	334	47.21	140	29.53	12	4.00	0	0.00	5.80	34	3200	8080	23100	14448
12	300.13	4882.8	62	268.40	893445	0	0	0	0	16	6.54	152	16.51	334	47.20	140	29.52	11	3.67	0	0.00	4.75	31	3200	8080	23100	14448
12	300.22	4882.8	62	5.48	881090	0	0	0	0	16	6.54	152	16.51	334	47.20	140	29.52	12	4.00	0	0.00	4.85	28	3200	8080	23100	14448
12	300.13	4882.8	62	109.36	930333	0	0	0	0	16	6.54	152	16.52	334	47.22	140	29.53	12	4.00	0	0.00	5.20	30	3200	8080	23100	14448
12	300.24	4883.2	62	85.27	894002	0	1	0	0	16	6.55	154	16.74	334	47.26	139	29.36	15	5.00	0	0.00	6.00	29	3200	8180	23100	14352
12	300.13	4883.2	62	79.58	949530	0	0	0	0	16	6.55	154	16.74	334	47.26	139	29.36	14	4.67	0	0.00	5.25	28	3200	8180	23100	14352
12	300.14	4882.8	62	253.80	899545	0	0	0	0	16	6.54	152	16.52	334	47.22	140	29.53	12	4.00	0	0.00	5.00	30	3200	8080	23100	14448
12	300.22	4882.8	62	128.56	932922	0	0	0	0	16	6.55	152	16.55	334	47.31	140	29.59	12	4.00	0	0.00	5.45	29	3200	8080	23100	14448
12	300.14	4882.8	62	59.08	951780	0	0	0	0	16	6.54	152	16.52	334	47.22	140	29.53	12	4.00	0	0.00	5.45	29	3200	8080	23100	14448
36	306.59	4887.6	61	64.58	1025842	0	0	0	0	16	6.53	152	16.49	334	47.15	142	29.59	10	3.33	0	0.00	5.25	29	3200	8080	23100	14496
36	308.51	4882.8	62	160.68	1002721	0	0	0	0	16	6.53	152	16.50	334	47.17	140	29.51	13	4.33	0	0.00	6.45	31	3200	8080	23100	14448
36	313.75	4882.8	62	4.87	1015031	0	0	0	0	16	6.54	152	16.52	334	47.22	140	29.53	12	4.00	0	0.00	5.75	30	3200	8080	23100	14448
36	312.44	4882.8	62	140.00	1034332	0	0	0	0	16	6.54	152	16.51	334	47.21	140	29.53	11	3.67	0	0.00	5.45	27	3200	8080	23100	14448
36	317.63	4882.8	62	7.63	1032405	0	0	0	0	16	6.53	152	16.50	334	47.17	140	29.50	12	4.00	0	0.00	5.85	29	3200	8080	23100	14448
36	316.76	4882.8	62	186.31	1054517	0	0	0	0	16	6.54	152	16.50	334	47.18	140	29.51	12	4.00	0	0.00	4.75	29	3200	8080	23100	14448
36	308.30	4882.8	62	26.49	1005252	0	0	0	0	16	6.55	152	16.55	334	47.31	140	29.59	12	4.00	0	0.00	5.75	35	3200	8080	23100	14448
36	306.77	4882.8	62	5.41	1011180	0	0	0	0	16	6.55	152	16.53	334	47.27	140	29.57	12	4.00	0	0.00	4.20	32	3200	8080	23100	14448
36	308.97	4882.8	62	244.73	1035168	0	0	0	0	16	6.54	152	16.50	334	47.19	140	29.51	12	4.00	0	0.00	5.50	28	3200	8080	23100	14448
36	306.18	4882.8	62	44.09	997373	0	0	0	0	16	6.55	152	16.53	334	47.26	140	29.56	12	4.00	0	0.00	4.85	28	3200	8080	23100	14448
36*	301.00	4883.2	68	297.84	994590	0	0	0	0	16	6.55	154	16.75	334	47.31	139	29.39	12	4.00	0	0.00	5.15	34	3200	8180	23100	14352
36*	300.99	4882.8	62	53.49	914782	0	0	0	0	16	6.55	152	16.55	334	47.31	140	29.59	12	4.00	0	0.00	5.45	29	3200	8080	23100	14448
36*	301.45	4887.6	61	198.74	943607	0	0	0	0	16	6.55	152	16.53	334	47.26	142	29.66	11	3.67	0	0.00	5.05	30	3200	8080	23100	14496
36*	317.02	4882.8	68	28.03	1032298	0	0	0	0	16	6.55	152	16.55	334	47.31	140	29.59	12	4.00	0	0.00	4.90	32	3200	8080	23100	14448
36*	300.99	4882.8	62	34.91	1003033	0	0	0	0	16	6.55	152	16.55	334	47.31	140	29.59	12	4.00	0	0.00	5.75	30	3200	8080	23100	14448
36*	307.55	4882.8	62	140.68	1029441	0	0	0	0	16	6.55	152	16.55	334	47.31	140	29.59	12	4.00	0	0.00	4.80	28	3200	8080	23100	14448
36*	300.92	4882.8	62	30.11	989799	0	0	0	0	16	6.55	152	16.55	334	47.31	140	29.59	12	4.00	0	0.00	5.75	35	3200	8080	23100	14448
36*	300.99	4882.8	62	247.14	895708	0	0	0	0	16	6.55	152	16.55	334	47.31	140	29.59	12	4.00	0	0.00	5.50	28	3200	8080	23100	14448
36*	301.08	4882.8	62	137.56	972002	0	0	0	0	16	6.55	152	16.55	334	47.31	140	29.59	12	4.00	0	0.00	6.45	33	3200	8080	23100	14448
36*	313.79	4887.6	61	210.79	999177	0	0	0	0	16	6.55	152	16.53	334	47.26	142	29.66	10	3.33	0	0.00	5.95	38	3200	8080	23100	14496

Table D.73: Results of all runs made with NSF network case 2, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.24	5544.0	80	200.15	98543	0	98543	0	0	24	8.66	104	9.96	356	47.62	174	33.77	6	3.00	0	0.00	5.50	37	4800	5520	26400	18720
1	300.13	5527.2	80	243.80	98437	0	98437	0	0	24	8.68	100	10.20	356	47.76	171	33.35	8	4.00	0	0.00	5.25	29	4800	5640	26400	18432
1	300.24	5541.6	80	64.40	98438	0	98438	0	0	24	8.66	100	10.18	356	47.64	171	33.52	9	4.50	0	0.00	5.85	30	4800	5640	26400	18576
1	300.13	5540.4	80	111.71	98405	0	98405	0	0	24	8.66	102	10.07	356	47.65	173	33.61	5	2.50	0	0.00	5.35	36	4800	5580	26400	18624
1	300.24	5540.4	80	107.58	98473	0	98473	0	0	24	8.66	102	10.07	356	47.65	173	33.61	6	3.00	0	0.00	5.30	36	4800	5580	26400	18624
1	300.22	5544.0	80	189.43	98583	0	98583	0	0	24	8.66	104	9.96	356	47.62	174	33.77	5	2.50	0	0.00	4.40	26	4800	5520	26400	18720
1	300.13	5534.4	80	117.67	98442	0	98442	0	0	24	8.67	104	9.97	356	47.70	173	33.65	6	3.00	0	0.00	4.05	29	4800	5520	26400	18624
1	300.24	5536.8	80	270.82	98524	0	98524	0	0	24	8.67	100	10.19	356	47.68	169	33.46	7	3.50	0	0.00	5.05	38	4800	5640	26400	18528
1	300.13	5541.6	80	48.06	98491	0	98491	0	0	24	8.66	100	10.18	356	47.64	171	33.52	10	5.00	0	0.00	5.00	37	4800	5640	26400	18576
1	300.13	5542.0	80	52.93	98729	0	98729	0	0	24	8.66	102	10.36	356	47.64	170	33.35	12	6.00	0	0.00	5.25	31	4800	5740	26400	18480
12	300.14	5530.0	80	226.67	968313	0	968313	0	0	24	8.67	106	10.15	356	47.68	170	33.38	8	4.00	0	0.00	5.30	39	4800	5620	26400	18480
12	300.25	5535.6	80	76.66	971192	0	971192	0	0	24	8.66	102	10.07	356	47.63	171	33.52	6	3.00	0	0.00	4.55	38	4800	5580	26400	18576
12	300.13	5527.2	80	178.96	961251	0	961251	0	0	24	8.66	100	10.18	356	47.64	171	33.26	8	4.00	0	0.00	4.10	29	4800	5640	26400	18432
12	300.25	5534.8	80	249.05	986818	0	986818	0	0	24	8.67	106	10.15	356	47.70	172	33.48	9	4.50	0	0.00	5.20	33	4800	5620	26400	18528
12	300.14	5535.6	80	75.19	966616	0	966616	0	0	24	8.66	102	10.07	356	47.65	171	33.53	7	3.50	0	0.00	5.05	29	4800	5580	26400	18576
12	300.24	5528.8	80	187.56	981813	0	981813	0	0	24	8.67	108	10.04	356	47.66	172	33.45	8	4.00	0	0.00	4.45	33	4800	5560	26400	18528
12	300.13	5534.4	80	7.30	948375	0	948375	0	0	24	8.67	104	9.97	356	47.70	173	33.65	6	3.00	0	0.00	5.20	37	4800	5520	26400	18624
12	300.14	5534.4	80	65.01	1011442	0	1011442	0	0	24	8.66	104	9.96	356	47.62	173	33.59	5	2.50	0	0.00	4.35	24	4800	5520	26400	18624
12	300.25	5528.8	80	108.42	955179	0	955179	0	0	24	8.67	108	10.04	356	47.69	172	33.47	8	4.00	0	0.00	6.10	37	4800	5560	26400	18528
12	300.13	5534.4	80	177.75	934738	0	934738	0	0	24	8.67	104	9.97	356	47.67	173	33.63	6	3.00	0	0.00	5.40	34	4800	5520	26400	18624
36	317.29	5527.2	80	295.01	1104126	0	1104126	0	0	24	8.65	100	10.16	356	47.57	171	33.21	8	4.00	0	0.00	4.95	32	4800	5640	26400	18432
36	316.10	5528.8	80	96.02	1067890	0	1067890	0	0	24	8.66	108	10.03	356	47.62	172	33.42	8	4.00	0	0.00	5.25	36	4800	5560	26400	18528
36	313.75	5528.8	80	170.26	1033572	0	1033572	0	0	24	8.67	108	10.04	356	47.67	172	33.45	8	4.00	0	0.00	5.25	36	4800	5560	26400	18528
36	318.21	5528.8	80	164.74	1095879	0	1095879	0	0	24	8.66	108	10.03	356	47.61	172	33.41	8	4.00	0	0.00	5.40	33	4800	5560	26400	18528
36	314.20	5528.8	80	115.03	1066025	0	1066025	0	0	24	8.66	108	10.03	356	47.61	172	33.41	8	4.00	0	0.00	5.50	35	4800	5560	26400	18528
36	311.77	5527.2	80	118.73	1060269	0	1060269	0	0	24	8.67	100	10.19	356	47.69	171	33.30	8	4.00	0	0.00	4.20	29	4800	5640	26400	18432
36	313.97	5534.4	80	38.27	1080912	0	1080912	0	0	24	8.66	104	9.96	356	47.62	173	33.59	4	2.00	0	0.00	4.60	33	4800	5520	26400	18624
36	316.87	5528.8	80	108.30	1089259	0	1089259	0	0	24	8.66	108	10.03	356	47.62	172	33.42	8	4.00	0	0.00	4.25	28	4800	5560	26400	18528
36	316.34	5527.2	80	9.42	1089072	0	1089072	0	0	24	8.67	100	10.19	356	47.70	171	33.30	8	4.00	0	0.00	3.75	29	4800	5640	26400	18432
36	308.61	5534.8	80	79.84	1053253	0	1053253	0	0	24	8.66	106	10.14	356	47.62	172	33.42	9	4.50	0	0.00	4.90	26	4800	5620	26400	18528
36*	314.42	5527.2	80	43.90	1050107	0	1050107	0	0	24	8.68	100	10.20	356	47.76	171	33.35	8	4.00	0	0.00	4.85	29	4800	5640	26400	18432
36*	300.91	5534.4	80	11.50	992081	0	992081	0	0	24	8.67	104	9.97	356	47.70	173	33.65	6	3.00	0	0.00	4.40	31	4800	5520	26400	18624
36*	300.94	5528.8	80	268.52	1034967	0	1034967	0	0	24	8.68	108	10.06	356	47.75	172	33.51	8	4.00	0	0.00	4.90	38	4800	5560	26400	18528
36*	310.50	5534.8	80	182.32	1010072	0	1010072	0	0	24	8.67	106	10.15	356	47.70	172	33.48	8	4.00	0	0.00	5.25	36	4800	5620	26400	18528
36*	300.80	5534.4	80	83.35	1010858	0	1010858	0	0	24	8.67	104	9.97	356	47.70	173	33.65	4	2.00	0	0.00	5.60	35	4800	5520	26400	18624
36*	308.76	5527.2	80	65.91	1024390	0	1024390	0	0	24	8.68	100	10.20	356	47.76	171	33.35	8	4.00	0	0.00	6.40	31	4800	5640	26400	18432
36*	313.52	5526.0	80	48.30	1062128	0	1062128	0	0	24	8.69	102	10.10	356	47.77	170	33.44	6	3.00	0	0.00	5.75	35	4800	5580	26400	18480
36*	300.90	5534.4	80	33.93	979043	0	979043	0	0	24	8.67	104	9.97	356	47.70	173	33.65	4	2.00	0	0.00	4.60	33	4800	5520	26400	18624
36*	301.09	5528.8	80	85.59	1023419	0	1023419	0	0	24	8.68	108	10.06	356	47.75	172	33.51	8	4.00	0	0.00	4.25	28	4800	5560	26400	18528
36*	300.91	5527.2	80	287.22	1035854	0	1035854	0	0	24	8.68	100	10.20	356	47.76	171	33.35	8	4.00	0	0.00	5.25	29	4800	5640	26400	18432

Table D.74: Results of all runs made with NSF network case 3, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.28	5390.4	59	124.38	35957	0	0	0	0	20	7.42	404	37.77	162	23.37	166	31.43	20	2.56	0	0.00	3.50	35	4000	20360	12600	16944
1	300.16	5400.4	60	163.85	35862	0	0	0	0	20	7.41	406	37.89	162	23.33	166	31.38	20	2.56	0	0.00	4.25	35	4000	20460	12600	16944
1	300.16	5395.6	60	232.69	35889	0	0	0	0	20	7.41	406	37.92	162	23.35	164	31.31	15	1.92	0	0.00	2.90	22	4000	20460	12600	16896
1	300.28	5396.4	59	220.18	36001	0	0	0	0	20	7.41	402	37.84	162	23.35	163	31.40	20	2.56	0	0.00	3.35	22	4000	20420	12600	16944
1	300.16	5396.8	60	67.10	35881	0	0	0	0	20	7.41	404	38.02	162	23.35	162	31.22	21	2.69	0	0.00	4.60	36	4000	20520	12600	16848
1	300.28	5400.4	58	33.99	35933	0	0	0	0	20	7.41	406	37.89	162	23.33	166	31.38	15	1.92	0	0.00	4.05	35	4000	20460	12600	16944
1	300.16	5396.0	60	285.59	36018	0	0	0	0	20	7.41	408	38.10	162	23.35	163	31.13	18	2.31	0	0.00	3.75	22	4000	20560	12600	16800
1	300.28	5396.0	59	58.92	35868	0	0	0	0	20	7.41	408	38.10	162	23.35	163	31.13	22	2.82	0	0.00	3.70	28	4000	20560	12600	16800
1	300.16	5395.2	59	132.21	35908	0	0	0	0	20	7.41	404	37.74	162	23.35	165	31.49	17	2.18	0	0.00	4.10	35	4000	20360	12600	16992
1	300.16	5374.8	60	190.54	35300	0	0	0	0	20	7.44	406	37.77	162	23.44	165	31.35	19	2.44	0	0.00	3.65	27	4000	20300	12600	16848
12	300.16	5386.8	60	295.56	351137	0	0	0	0	20	7.40	402	37.78	162	23.31	162	31.17	19	2.44	0	0.00	4.40	32	4000	20420	12600	16848
12	300.24	5386.8	59	172.36	345891	0	0	0	0	20	7.41	402	37.84	162	23.35	162	31.22	18	2.31	0	0.00	4.20	36	4000	20420	12600	16848
12	300.25	5373.6	59	168.89	338127	0	0	0	0	20	7.41	400	37.91	162	23.33	160	30.84	24	3.08	0	0.00	4.10	35	4000	20480	12600	16656
12	300.33	5376.4	60	221.77	349221	0	0	0	0	20	7.41	406	37.92	162	23.35	162	30.96	16	2.05	0	0.00	3.70	36	4000	20460	12600	16704
12	300.19	5386.8	58	292.31	332580	0	0	0	0	20	7.41	402	37.85	162	23.35	162	31.23	17	2.18	0	0.00	3.55	31	4000	20420	12600	16848
12	300.41	5385.6	60	281.80	354427	0	0	0	0	20	7.41	404	37.74	162	23.35	164	31.32	15	1.92	0	0.00	3.90	26	4000	20360	12600	16896
12	300.18	5376.8	59	145.49	345364	0	0	0	0	20	7.41	400	37.66	162	23.35	162	31.23	18	2.31	0	0.00	4.30	36	4000	20320	12600	16848
12	300.32	5386.0	60	89.54	328298	0	0	0	0	20	7.40	406	37.86	162	23.31	163	31.09	18	2.31	0	0.00	4.75	32	4000	20460	12600	16800
12	300.18	5382.8	60	221.66	346922	0	0	0	0	20	7.41	398	37.73	162	23.33	162	31.19	17	2.18	0	0.00	3.70	22	4000	20380	12600	16848
12	300.28	5387.6	61	74.97	342816	0	0	0	0	20	7.41	406	38.22	162	23.35	160	30.87	25	3.21	0	0.00	4.45	37	4000	20620	12600	16656
36	311.45	5377.2	59	3.67	391295	0	0	0	0	20	7.41	402	37.81	162	23.33	161	31.02	24	3.08	0	0.00	3.75	36	4000	20420	12600	16752
36	316.96	5390.8	58	201.74	399573	0	0	0	0	20	7.41	406	37.89	162	23.34	165	31.20	17	2.18	0	0.00	3.95	30	4000	20460	12600	16848
36	314.22	5394.8	59	62.78	395581	0	0	0	0	20	7.41	410	38.00	162	23.36	165	31.23	17	2.18	0	0.00	4.55	36	4000	20500	12600	16848
36	312.17	5386.8	60	160.98	384775	0	0	0	0	20	7.41	402	37.81	162	23.33	162	31.20	21	2.69	0	0.00	4.10	35	4000	20420	12600	16848
36	306.38	5391.2	59	214.03	385379	0	0	0	0	20	7.41	400	37.62	162	23.33	165	31.46	19	2.44	0	0.00	4.15	32	4000	20320	12600	16992
36	315.15	5385.6	59	182.51	390956	0	0	0	0	20	7.40	404	37.66	162	23.31	164	31.26	19	2.44	0	0.00	4.30	26	4000	20360	12600	16896
36	314.28	5390.4	59	193.86	394901	0	0	0	0	20	7.40	404	37.67	162	23.31	166	31.35	23	2.95	0	0.00	4.40	30	4000	20360	12600	16944
36	316.60	5384.8	60	13.10	390839	0	0	0	0	20	7.43	408	37.88	162	23.40	165	31.29	20	2.56	0	0.00	4.00	29	4000	20400	12600	16848
36	317.02	5386.8	60	234.48	390780	0	0	0	0	20	7.41	402	37.84	162	23.35	162	31.22	17	2.18	0	0.00	3.95	32	4000	20420	12600	16848
36	308.02	5386.8	60	77.34	379993	0	0	0	0	20	7.39	402	37.75	162	23.29	162	31.14	26	3.33	0	0.00	4.90	29	4000	20420	12600	16848
36*	314.40	5384.8	59	168.67	387516	0	0	0	0	20	7.43	408	37.88	162	23.40	165	31.29	18	2.31	0	0.00	3.55	16	4000	20400	12600	16848
36*	316.15	5377.2	59	13.31	395323	0	0	0	0	20	7.44	402	37.98	162	23.43	161	31.15	24	3.08	0	0.00	3.75	36	4000	20420	12600	16752
36*	301.02	5385.6	60	77.97	378366	0	0	0	0	20	7.43	404	37.80	162	23.40	164	31.37	15	1.92	0	0.00	4.65	29	4000	20360	12600	16896
36*	310.86	5386.8	59	183.50	379005	0	0	0	0	20	7.43	402	37.91	162	23.39	162	31.28	19	2.44	0	0.00	4.70	31	4000	20420	12600	16848
36*	300.85	5376.4	60	219.48	372782	0	0	0	0	20	7.44	406	38.06	162	23.44	162	31.07	16	2.05	0	0.00	3.70	36	4000	20460	12600	16704
36*	309.11	5386.8	59	175.69	377215	0	0	0	0	20	7.43	402	37.91	162	23.39	162	31.28	18	2.31	0	0.00	3.80	31	4000	20420	12600	16848
36*	301.14	5391.6	60	178.51	374582	0	0	0	0	20	7.42	402	37.87	162	23.37	164	31.34	18	2.31	0	0.00	4.15	22	4000	20420	12600	16896
36*	308.57	5386.8	60	147.08	379327	0	0	0	0	20	7.43	402	37.91	162	23.39	162	31.28	26	3.33	0	0.00	4.90	29	4000	20420	12600	16848
36*	300.78	5384.8	59	122.96	369724	0	0	0	0	20	7.43	408	37.88	162	23.40	165	31.29	18	2.31	0	0.00	3.55	16	4000	20400	12600	16848
36*	315.29	5385.6	60	41.07	371100	0	0	0	0	20	7.43	404	37.80	162	23.40	164	31.37	16	2.05	0	0.00	4.55	36	4000	20360	12600	16896

Table D.75: Results of all runs made with NSF network case 4, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.32	6788.4	80	241.39	42196	0	18862	771	0	14	4.12	190	15.41	442	45.96	217	34.51	13	3.33	0	0.00	7.45	47	2800	10460	31200	23424
1	300.18	6780.0	80	19.97	42241	0	18699	740	0	18	5.31	192	15.58	438	45.13	219	33.98	8	2.05	0	0.00	7.90	50	3600	10560	30600	23040
1	300.19	6768.4	80	64.83	42061	0	18734	740	0	18	5.32	198	15.57	438	45.21	218	33.90	11	2.82	0	0.00	7.95	43	3600	10540	30600	22944
1	300.32	6774.0	80	213.24	42491	0	19125	788	0	18	5.31	194	15.50	438	45.17	216	34.01	11	2.82	0	0.00	8.05	40	3600	10500	30600	23040
1	300.19	6786.0	79	214.20	42282	0	18846	725	0	18	5.31	190	15.65	438	45.09	216	33.95	16	4.10	0	0.00	8.50	44	3600	10620	30600	23040
1	300.32	6789.2	80	162.69	42379	0	18851	768	0	16	4.71	192	15.55	440	45.51	218	34.22	11	2.82	0	0.00	8.05	47	3200	10560	30900	23232
1	300.18	6784.4	80	96.45	42338	0	18782	727	0	16	4.72	192	15.57	440	45.55	216	34.17	11	2.82	0	0.00	8.05	44	3200	10560	30900	23184
1	300.18	6790.0	80	126.19	42297	0	18879	714	0	16	4.71	204	15.49	440	45.51	220	34.29	12	3.08	0	0.00	8.20	45	3200	10520	30900	23280
1	300.32	6774.4	80	158.15	42389	0	18865	752	0	16	4.72	190	15.44	440	45.61	216	34.22	10	2.56	0	0.00	7.50	47	3200	10460	30900	23184
1	300.18	6779.6	80	248.72	42401	0	18967	755	0	16	4.72	192	15.58	440	45.58	217	34.13	13	3.33	0	0.00	7.70	46	3200	10560	30900	23136
12	300.19	6766.8	80	145.46	418018	0	186316	7347	0	18	5.31	190	15.66	438	45.11	217	33.68	12	3.08	0	0.00	7.65	40	3600	10620	30600	22848
12	300.26	6770.0	80	113.63	408096	0	181476	7125	0	18	5.32	190	15.45	438	45.20	216	34.03	10	2.56	0	0.00	7.75	48	3600	10460	30600	23040
12	300.44	6780.4	80	51.42	416615	0	185553	7376	0	18	5.31	194	15.72	438	45.12	218	33.83	15	3.85	0	0.00	7.25	41	3600	10660	30600	22944
12	300.24	6768.0	80	257.49	382581	0	170565	6726	0	16	4.72	198	15.56	440	45.60	216	34.00	12	3.08	0	0.00	7.75	47	3200	10540	30900	23040
12	300.78	6748.8	80	239.26	384789	0	171506	6785	0	18	5.30	196	15.38	438	45.08	217	33.66	11	2.82	0	0.00	8.20	44	3600	10440	30600	22848
12	300.32	6752.8	80	130.74	380648	0	169241	6682	0	18	5.30	200	15.42	438	45.02	217	33.62	13	3.33	0	0.00	8.50	42	3600	10480	30600	22848
12	300.19	6764.4	80	290.10	394049	0	175367	6883	0	16	4.72	196	15.62	440	45.55	215	33.82	12	3.08	0	0.00	7.20	49	3200	10600	30900	22944
12	300.33	6761.2	79	66.27	387445	0	173054	6737	0	16	4.72	188	15.51	440	45.54	214	33.89	12	3.08	0	0.00	7.75	41	3200	10520	30900	22992
12	300.21	6758.8	80	199.91	408188	0	181714	7118	0	16	4.71	200	15.65	440	45.46	214	33.61	18	4.62	0	0.00	7.55	44	3200	10640	30900	22848
12	300.21	6771.2	79	49.14	390102	0	174101	6860	0	18	5.31	188	15.52	438	45.14	217	33.91	11	2.82	0	0.00	8.30	43	3600	10520	30600	22992
36	315.96	6767.6	80	262.72	446173	0	198668	7872	0	16	4.69	196	15.30	440	45.28	217	33.90	14	3.59	0	0.00	9.15	46	3200	10440	30900	23136
36	312.87	6755.6	80	233.45	444894	0	198091	7702	0	18	5.30	190	15.41	438	45.08	216	33.73	10	2.56	0	0.00	8.00	42	3600	10460	30600	22896
36	316.23	6760.4	80	249.85	454515	0	202335	8053	0	16	4.69	192	15.48	440	45.31	215	33.64	10	2.56	0	0.00	8.05	44	3200	10560	30900	22944
36	307.32	6766.4	80	112.83	439787	0	196127	7769	0	16	4.71	190	15.65	440	45.52	215	33.80	13	3.33	0	0.00	8.25	49	3200	10620	30900	22944
36	307.24	6763.6	80	268.71	442331	0	196846	7730	0	18	5.28	198	15.47	438	44.92	216	33.61	17	4.36	0	0.00	7.20	41	3600	10540	30600	22896
36	311.25	6777.2	80	287.46	443237	0	197694	7836	0	16	4.71	196	15.35	440	45.43	218	34.16	10	2.56	0	0.00	7.40	44	3200	10440	30900	23232
36	313.75	6758.0	80	98.03	452320	0	201703	7977	0	16	4.70	196	15.34	440	45.39	216	33.84	9	2.31	0	0.00	7.45	49	3200	10440	30900	23040
36	314.14	6767.6	80	134.96	452694	0	201743	8042	0	16	4.70	196	15.34	440	45.39	217	33.99	9	2.31	0	0.00	8.25	45	3200	10440	30900	23136
36	314.81	6771.2	79	57.25	451888	0	200767	7909	0	18	5.28	188	15.43	438	44.89	217	33.73	11	2.82	0	0.00	8.30	43	3600	10520	30600	22992
36	313.34	6759.6	80	54.46	451884	0	201558	7862	0	18	5.31	194	15.47	438	45.10	216	33.74	9	2.31	0	0.00	7.80	42	3600	10500	30600	22896
36*	300.86	6770.4	80	293.69	434059	0	193324	7603	0	18	5.32	192	15.60	438	45.20	215	33.89	11	2.82	0	0.00	8.35	45	3600	10560	30600	22944
36*	307.16	6754.4	80	176.59	396815	0	177176	7132	0	18	5.33	192	15.40	438	45.30	218	33.97	10	2.56	0	0.00	8.35	48	3600	10400	30600	22944
36*	300.75	6777.2	80	154.77	415161	0	184926	7432	0	16	4.72	196	15.40	440	45.59	218	34.28	9	2.31	0	0.00	7.65	39	3200	10440	30900	23232
36*	308.76	6754.8	80	261.75	426108	0	190275	7498	0	18	5.33	194	15.54	438	45.30	217	33.82	13	3.33	0	0.00	8.15	43	3600	10500	30600	22848
36*	301.13	6760.0	80	194.30	403816	0	179326	7154	0	16	4.73	190	15.47	440	45.71	216	34.08	9	2.31	0	0.00	7.15	39	3200	10460	30900	23040
36*	314.15	6770.4	80	187.68	399788	0	178303	7042	0	16	4.73	186	15.39	440	45.64	213	34.24	9	2.31	0	0.00	8.20	48	3200	10420	30900	23184
36*	300.94	6764.8	80	93.85	420979	0	187129	7543	0	18	5.32	196	15.67	438	45.23	217	33.77	13	3.33	0	0.00	8.80	46	3600	10600	30600	22848
36*	308.13	6768.0	80	266.40	405734	0	181074	7145	0	18	5.32	196	15.43	438	45.21	219	34.04	10	2.56	0	0.00	8.15	44	3600	10440	30600	23040
36*	300.92	6768.4	80	150.77	386061	0	172102	6726	0	16	4.73	192	15.37	440	45.65	216	34.25	12	3.08	0	0.00	7.45	40	3200	10400	30900	23184
36*	300.91	6766.4	80	71.62	407999	0	181652	7160	0	16	4.73	190	15.70	440	45.67	212	33.91	15	3.85	0	0.00	7.45	47	3200	10620	30900	22944

Table D.76: Results of all runs made with NSF network case 5, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.19	7349.2	80	21.22	39648	0	8013	0	0	28	7.62	138	9.82	466	47.35	241	35.20	17	6.54	0	0.00	6.55	33	5600	7220	34800	25872
1	300.32	7356.0	79	71.59	39494	0	8018	0	0	28	7.61	140	10.17	466	47.31	239	34.91	19	7.31	0	0.00	6.45	31	5600	7480	34800	25680
1	300.19	7345.2	79	74.58	39504	0	8323	0	0	28	7.62	134	9.78	466	47.38	241	35.22	17	6.54	0	0.00	5.45	27	5600	7180	34800	25872
1	300.32	7358.8	78	235.03	39516	0	8203	0	0	24	6.52	134	9.76	470	48.11	240	35.61	13	5.00	0	0.00	6.10	34	4800	7180	35400	26208
1	300.18	7359.2	79	123.29	39556	0	8075	0	0	28	7.61	140	9.95	466	47.29	241	35.16	15	5.77	0	0.00	7.15	36	5600	7320	34800	25872
1	300.32	7344.4	78	58.64	39379	0	8186	0	0	28	7.62	138	9.83	466	47.38	239	35.16	11	4.23	0	0.00	6.20	27	5600	7220	34800	25824
1	300.32	7350.4	79	280.33	39522	0	8072	0	0	28	7.62	136	9.90	466	47.34	239	35.13	15	5.77	0	0.00	5.45	26	5600	7280	34800	25824
1	300.18	7360.4	78	274.56	39615	0	8099	0	0	28	7.61	138	10.03	466	47.28	239	35.09	18	6.92	0	0.00	5.00	22	5600	7380	34800	25824
1	300.33	7354.8	77	86.00	39448	0	8023	0	0	28	7.61	142	10.09	466	47.32	238	34.98	15	5.77	0	0.00	5.45	33	5600	7420	34800	25728
1	300.18	7339.6	79	90.59	39482	0	8073	0	0	28	7.63	138	9.84	466	47.41	240	35.12	14	5.38	0	0.00	5.30	28	5600	7220	34800	25776
12	300.19	7344.8	78	164.22	372126	0	76465	0	0	28	7.61	140	9.95	466	47.30	238	34.97	13	5.00	0	0.00	6.60	34	5600	7320	34800	25728
12	300.21	7330.8	79	126.28	407646	0	83692	0	0	28	7.62	134	9.77	466	47.35	238	35.01	15	5.77	0	0.00	6.35	33	5600	7180	34800	25728
12	300.35	7340.0	80	50.19	381650	0	78395	0	0	28	7.61	140	9.95	466	47.29	239	34.89	17	6.54	0	0.00	6.25	33	5600	7320	34800	25680
12	300.19	7340.8	78	112.23	389127	0	79840	0	0	28	7.61	136	9.89	466	47.29	238	34.96	15	5.77	0	0.00	6.50	29	5600	7280	34800	25728
12	300.35	7343.6	79	130.42	368112	0	75647	0	0	28	7.62	142	9.88	466	47.38	240	35.09	12	4.62	0	0.00	5.40	29	5600	7260	34800	25776
12	300.19	7343.6	80	146.08	375647	0	77058	0	0	28	7.62	142	9.88	466	47.37	240	35.08	16	6.15	0	0.00	7.50	35	5600	7260	34800	25776
12	300.33	7328.8	78	285.15	388491	0	79793	0	0	28	7.62	140	9.75	466	47.38	238	35.03	15	5.77	0	0.00	6.25	38	5600	7160	34800	25728
12	300.19	7340.8	79	141.12	388330	0	79682	0	0	28	7.61	136	9.90	466	47.32	238	34.98	13	5.00	0	0.00	5.55	31	5600	7280	34800	25728
12	300.33	7340.4	79	150.23	393606	0	80479	0	0	28	7.62	134	9.77	466	47.34	239	35.13	13	5.00	0	0.00	6.80	36	5600	7180	34800	25824
12	300.21	7346.4	78	57.42	384752	0	79287	0	0	28	7.61	132	9.84	466	47.29	239	35.09	16	6.15	0	0.00	6.30	33	5600	7240	34800	25824
36	315.56	7346.4	79	25.33	403912	0	82447	0	0	28	7.61	132	9.84	466	47.28	239	35.09	15	5.77	0	0.00	4.75	23	5600	7240	34800	25824
36	306.79	7340.8	78	156.09	418568	0	86356	0	0	28	7.60	136	9.88	466	47.23	238	34.92	16	6.15	0	0.00	5.90	35	5600	7280	34800	25728
36	306.03	7339.6	80	30.39	417252	0	85787	0	0	28	7.61	138	9.81	466	47.28	240	35.02	12	4.62	0	0.00	6.90	30	5600	7220	34800	25776
36	309.78	7335.6	79	247.32	426976	0	87562	0	0	28	7.62	134	9.76	466	47.32	240	35.05	13	5.00	0	0.00	5.80	32	5600	7180	34800	25776
36	306.09	7345.6	80	139.09	414035	0	85176	0	0	28	7.61	136	9.90	466	47.32	240	35.05	15	5.77	0	0.00	5.90	35	5600	7280	34800	25776
36	310.41	7340.0	79	297.10	410167	0	84305	0	0	28	7.60	140	9.94	466	47.25	239	34.86	16	6.15	0	0.00	6.15	36	5600	7320	34800	25680
36	318.35	7340.0	79	16.43	430765	0	88777	0	0	28	7.60	140	9.94	466	47.23	239	34.86	15	5.77	0	0.00	6.45	26	5600	7320	34800	25680
36	313.12	7340.8	79	53.40	435068	0	88961	0	0	28	7.62	136	9.90	466	47.33	238	34.99	17	6.54	0	0.00	6.40	38	5600	7280	34800	25728
36	315.45	7343.6	79	226.78	432024	0	88978	0	0	28	7.61	142	9.87	466	47.29	240	35.03	13	5.00	0	0.00	5.60	27	5600	7260	34800	25776
36	305.57	7340.0	79	63.87	411487	0	84619	0	0	28	7.60	140	9.94	466	47.25	239	34.86	16	6.15	0	0.00	7.20	36	5600	7320	34800	25680
36*	315.40	7340.0	78	218.23	397175	0	81404	0	0	28	7.63	140	9.97	466	47.41	239	34.99	16	6.15	0	0.00	5.60	25	5600	7320	34800	25680
36*	313.84	7336.8	79	107.76	420849	0	86147	0	0	28	7.63	132	9.87	466	47.43	238	35.07	14	5.38	0	0.00	6.25	34	5600	7240	34800	25728
36*	310.69	7340.8	79	38.72	416799	0	85331	0	0	28	7.63	136	9.92	466	47.41	238	35.05	17	6.54	0	0.00	6.15	31	5600	7280	34800	25728
36*	310.27	7344.8	79	53.60	410129	0	84483	0	0	28	7.62	140	9.97	466	47.38	238	35.03	16	6.15	0	0.00	5.65	33	5600	7320	34800	25728
36*	313.65	7343.6	80	73.91	426539	0	87870	0	0	28	7.63	142	9.89	466	47.39	240	35.10	14	5.38	0	0.00	6.75	35	5600	7260	34800	25776
36*	301.08	7335.6	80	39.80	416614	0	85785	0	0	28	7.63	134	9.79	466	47.44	240	35.14	16	6.15	0	0.00	6.30	35	5600	7180	34800	25776
36*	300.88	7340.8	79	29.86	408641	0	84011	0	0	28	7.63	136	9.92	466	47.41	238	35.05	15	5.77	0	0.00	5.85	24	5600	7280	34800	25728
36*	310.92	7336.8	77	1.20	432461	0	88706	0	0	28	7.63	132	9.87	466	47.43	238	35.07	14	5.38	0	0.00	6.00	35	5600	7240	34800	25728
36*	300.85	7334.0	80	129.12	399481	0	81946	0	0	28	7.64	142	9.90	466	47.45	239	35.02	21	8.08	0	0.00	7.25	30	5600	7260	34800	25680
36*	301.33	7340.8	79	263.58	391877	0	80374	0	0	28	7.63	136	9.92	466	47.41	238	35.05	18	6.92	0	0.00	6.05	32	5600	7280	34800	25728

Table D.77: Results of all runs made with NSF network case 6, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.26	7811.6	80	253.39	11601	0	11601	2039	0	24	6.14	490	35.05	214	21.51	260	37.30	39	3.85	0	0.00	5.15	41	4800	27380	16800	29136
1	300.38	7854.0	80	44.80	11620	0	11620	2116	0	14	3.57	504	34.94	224	23.30	251	38.20	33	3.25	0	0.00	4.80	35	2800	27440	18300	30000
1	300.22	7857.6	80	16.52	11628	0	11628	2087	0	14	3.56	506	34.85	224	23.29	258	38.30	35	3.45	0	0.00	4.00	33	2800	27380	18300	30096
1	300.36	7823.6	80	25.77	11559	0	11559	2063	0	16	4.09	502	34.74	222	23.01	254	38.16	26	2.56	0	0.00	5.40	43	3200	27180	18000	29856
1	300.21	7804.4	80	104.46	11593	0	11593	2035	0	16	4.10	510	35.13	222	23.06	248	37.70	33	3.25	0	0.00	4.30	20	3200	27420	18000	29424
1	300.38	7825.2	80	81.54	11601	0	11601	2095	0	20	5.11	506	34.99	218	22.24	259	37.66	38	3.75	0	0.00	4.25	38	4000	27380	17400	29472
1	300.22	7832.4	80	292.16	11563	0	11563	2007	0	16	4.09	506	34.75	222	22.98	253	38.18	38	3.75	0	0.00	3.20	43	3200	27220	18000	29904
1	300.38	7830.4	80	51.73	11589	0	11589	2073	0	14	3.58	498	34.86	224	23.37	244	38.19	35	3.45	0	0.00	4.20	41	2800	27300	18300	29904
1	300.22	7808.8	80	207.57	11551	0	11551	2028	0	16	4.10	492	34.99	222	23.05	257	37.87	41	4.04	0	0.00	3.40	23	3200	27320	18000	29568
1	300.36	7785.2	80	61.79	11663	0	11663	2187	0	14	3.60	496	34.73	224	23.51	251	38.16	31	3.06	0	0.00	4.75	33	2800	27040	18300	29712
12	300.39	7805.6	80	59.16	116185	0	116185	21144	0	16	4.08	500	34.74	222	22.96	256	37.77	32	3.16	0	0.00	5.25	45	3200	27240	18000	29616
12	300.24	7792.0	80	37.86	130299	0	130299	19751	0	14	3.57	498	34.78	224	23.31	249	37.60	33	3.25	0	0.00	5.15	42	2800	27300	18300	29520
12	300.25	7798.8	80	50.06	106372	0	106372	19314	0	18	4.59	498	34.42	218	22.20	258	38.03	28	2.76	0	0.00	5.05	37	3600	26980	17400	29808
12	300.39	7822.4	80	112.55	113731	0	113731	20887	0	14	3.57	498	34.45	224	23.36	257	38.49	28	2.76	0	0.00	3.80	26	2800	26980	18300	30144
12	300.25	7805.6	80	18.00	115726	0	115726	20900	0	14	3.58	494	34.63	224	23.38	251	38.15	31	3.06	0	0.00	4.35	26	2800	27100	18300	29856
12	300.24	7801.2	80	293.06	110656	0	110656	19945	0	16	4.08	494	34.51	222	22.92	257	37.84	27	2.66	0	0.00	4.15	24	3200	27100	18000	29712
12	300.27	7770.0	80	226.20	115977	0	115977	21162	0	16	4.10	506	34.88	222	23.07	254	37.52	36	3.55	0	0.00	4.15	41	3200	27220	18000	29280
12	300.27	7784.8	80	71.59	121458	0	121458	22149	0	14	3.57	502	34.67	224	23.34	251	37.72	32	3.16	0	0.00	4.80	44	2800	27180	18300	29568
12	300.96	7797.2	80	123.60	118544	0	118544	21763	0	14	3.58	508	34.75	224	23.41	251	38.01	33	3.25	0	0.00	5.05	43	2800	27160	18300	29712
12	300.66	7795.6	80	212.19	115352	0	115352	20849	0	14	3.59	492	34.60	224	23.45	251	38.26	30	2.96	0	0.00	3.45	26	2800	27000	18300	29856
36	313.42	7796.0	80	277.04	127466	0	127466	22997	0	20	5.09	504	34.69	218	22.13	257	37.23	33	3.25	0	0.00	4.10	28	4000	27280	17400	29280
36	325.32	7810.8	80	99.29	134734	0	134734	24156	0	16	4.04	502	34.52	222	22.73	251	37.34	38	3.75	0	0.00	5.75	48	3200	27340	18000	29568
36	317.62	7796.0	80	251.10	130742	0	130742	23657	0	16	4.05	492	34.20	222	22.80	256	37.70	28	2.76	0	0.00	4.45	35	3200	27000	18000	29760
36	328.63	7804.0	80	175.47	131415	0	131415	23710	0	16	4.05	502	34.37	220	22.38	256	37.63	30	2.96	0	0.00	4.75	44	3200	27180	17700	29760
36	312.92	7805.6	80	16.49	127612	0	127612	23014	0	14	3.55	494	34.35	224	23.20	251	37.85	31	3.06	0	0.00	4.35	26	2800	27100	18300	29856
36	308.61	7805.2	80	239.12	129406	0	129406	23516	0	16	4.08	498	34.63	222	22.97	254	37.91	31	3.06	0	0.00	4.95	43	3200	27140	18000	29712
36	307.74	7797.2	80	200.09	121933	0	121933	22182	0	18	4.59	496	34.66	220	22.56	253	37.56	27	2.66	0	0.00	6.00	44	3600	27200	17700	29472
36	308.47	7791.2	80	34.80	127507	0	127507	23112	0	14	3.55	494	34.35	224	23.20	248	37.66	30	2.96	0	0.00	3.10	25	2800	27100	18300	29712
36	314.96	7774.4	80	286.65	128245	0	128245	23052	0	14	3.56	506	34.61	224	23.27	254	37.41	31	3.06	0	0.00	4.10	38	2800	27220	18300	29424
36	307.46	7799.2	80	46.71	125452	0	125452	22879	0	16	4.06	500	34.37	222	22.85	251	37.71	30	2.96	0	0.00	5.00	29	3200	27080	18000	29712
36*	315.21	7808.8	80	232.49	132945	1	132945	24045	0	16	4.10	492	34.99	222	23.05	257	37.87	41	4.04	0	0.00	3.40	23	3200	27320	18000	29568
36*	301.33	7820.4	80	85.99	123857	2	123857	22390	0	20	5.11	498	34.70	218	22.25	258	37.93	27	2.66	0	0.00	4.55	28	4000	27140	17400	29664
36*	300.97	7798.8	80	185.95	118764	0	118764	21433	0	18	4.62	498	34.60	218	22.31	258	38.22	28	2.76	0	0.00	5.05	37	3600	26980	17400	29808
36*	308.12	7796.0	80	198.31	126511	0	126511	23012	0	16	4.10	494	34.76	222	23.09	253	38.17	27	2.66	0	0.00	4.65	37	3200	27100	18000	29760
36*	313.22	7804.0	80	66.41	128815	1	128815	23393	0	14	3.59	502	34.83	224	23.45	247	38.13	31	3.06	0	0.00	4.65	42	2800	27180	18300	29760
36*	313.92	7801.6	79	211.44	130611	1	130611	23926	0	16	4.10	496	34.86	222	23.07	244	37.96	33	3.25	0	0.00	4.30	40	3200	27200	18000	29616
36*	301.19	7796.0	80	265.62	125441	0	125441	22651	0	18	4.62	498	34.81	220	22.70	246	37.87	27	2.66	0	0.00	6.05	49	3600	27140	17700	29520
36*	307.26	7807.2	80	37.47	126119	1	126119	22963	0	14	3.59	510	34.92	224	23.44	248	38.06	38	3.75	0	0.00	3.75	40	2800	27260	18300	29712
36*	314.20	7791.2	80	35.57	127640	1	127640	22973	0	14	3.59	494	34.78	224	23.49	248	38.14	30	2.96	0	0.00	3.10	25	2800	27100	18300	29712
36*	301.33	7795.6	80	202.57	125081	0	125081	22596	0	14	3.59	492	34.63	224	23.47	251	38.30	30	2.96	0	0.00	3.45	26	2800	27000	18300	29856

Table D.78: Results of all runs made with NSF network case 7, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
#T	t_E	C	CA	t_{sol}	#i	#IS	$\#G_U$	$\#LS_U$	UD	#IM	C_{IM}	#MX	C_{MX}	#TX	C_{TX}	#3R	C_{3R}	#10G	%10G	#40G	%40G	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.38	8378.0	80	16.10	11565	0	11565	491	0	20	4.77	228	16.66	574	48.20	238	30.37	23	4.54	0	0.00	3.80	28	4000	13960	40380	25440
1	300.25	8388.4	80	254.16	11583	0	11583	545	0	18	4.29	234	16.43	576	48.50	239	30.79	21	4.14	0	0.00	2.85	25	3600	13780	40680	25824
1	300.22	8384.0	80	258.24	11628	0	11628	530	0	20	4.77	226	16.72	574	48.16	241	30.34	27	5.33	0	0.00	3.45	27	4000	14020	40380	25440
1	300.41	8380.8	80	74.13	11561	0	11561	497	0	20	4.77	234	16.63	574	48.18	240	30.41	23	4.54	0	0.00	3.85	23	4000	13940	40380	25488
1	300.21	8359.6	80	93.16	11603	0	11603	513	0	20	4.78	232	16.36	574	48.30	242	30.55	20	3.94	0	0.00	3.35	23	4000	13680	40380	25536
1	300.39	8392.4	80	190.16	11573	0	11573	499	0	20	4.77	228	16.63	574	48.12	244	30.48	22	4.34	0	0.00	3.40	23	4000	13960	40380	25584
1	300.39	8349.2	80	169.88	11617	0	11617	524	0	18	4.31	230	16.27	576	48.72	240	30.70	20	3.94	0	0.00	3.80	26	3600	13580	40680	25632
1	300.39	8370.4	80	230.02	11664	0	11664	550	0	20	4.78	230	16.42	574	48.24	241	30.56	22	4.34	0	0.00	3.00	16	4000	13740	40380	25584
1	300.24	8381.6	80	260.61	11614	0	11614	532	0	20	4.77	230	16.58	574	48.18	239	30.47	24	4.73	0	0.00	3.15	19	4000	13900	40380	25536
1	300.39	8390.0	80	99.28	11608	0	11608	535	0	20	4.77	232	16.50	574	48.13	245	30.61	24	4.73	0	0.00	4.55	23	4000	13840	40380	25680
12	300.25	8352.4	79	274.90	104660	0	104660	4628	0	20	4.77	228	16.45	574	48.13	240	30.21	18	3.55	0	0.00	3.15	22	4000	13800	40380	25344
12	300.41	8356.4	80	123.23	115526	0	115526	5125	0	20	4.77	232	16.50	574	48.15	240	30.22	18	3.55	0	0.00	4.95	25	4000	13840	40380	25344
12	300.41	8355.6	80	77.77	116726	0	116726	5124	0	20	4.77	236	16.56	574	48.17	241	30.17	22	4.34	0	0.00	4.80	23	4000	13880	40380	25296
12	300.27	8338.0	80	145.53	117233	0	117233	5176	0	20	4.77	236	16.73	574	48.11	236	29.74	30	5.92	0	0.00	4.80	26	4000	14040	40380	24960
12	300.42	8365.6	80	297.73	117117	0	117117	5257	0	20	4.77	230	16.38	574	48.13	242	30.44	20	3.94	0	0.00	3.40	21	4000	13740	40380	25536
12	300.27	8372.4	80	94.83	117733	0	117733	5347	0	20	4.76	224	16.39	574	48.10	241	30.47	15	2.96	0	0.00	4.45	24	4000	13760	40380	25584
12	300.42	8362.0	80	152.82	115576	0	115576	5111	0	20	4.77	228	16.46	574	48.17	241	30.35	21	4.14	0	0.00	2.40	24	4000	13800	40380	25440
12	300.24	8372.0	80	45.97	114942	0	114942	5170	0	20	4.76	230	16.56	574	48.10	241	30.30	18	3.55	0	0.00	2.80	19	4000	13900	40380	25440
12	300.42	8351.6	80	31.79	112656	0	112656	5067	0	20	4.77	232	16.51	574	48.16	241	30.17	16	3.16	0	0.00	3.45	19	4000	13840	40380	25296
12	300.63	8370.8	80	285.56	113018	0	113018	5126	0	20	4.77	232	16.51	574	48.16	243	30.40	17	3.35	0	0.00	3.95	19	4000	13840	40380	25488
36	317.46	8352.4	80	15.49	129062	0	129062	5897	0	20	4.76	228	16.42	574	48.03	240	30.15	21	4.14	0	0.00	5.00	32	4000	13800	40380	25344
36	316.13	8363.2	80	129.40	130578	0	130578	5800	0	20	4.77	226	16.54	574	48.20	239	30.31	18	3.55	0	0.00	4.20	26	4000	13860	40380	25392
36	317.13	8368.4	80	2.87	124304	0	124304	5513	0	20	4.76	228	16.62	574	48.08	240	30.18	24	4.73	0	0.00	4.05	23	4000	13960	40380	25344
36	308.80	8365.6	80	44.49	122884	0	122884	5462	0	20	4.77	230	16.37	574	48.11	242	30.42	19	3.75	0	0.00	4.45	23	4000	13740	40380	25536
36	314.03	8370.8	80	125.48	127378	0	127378	5713	0	20	4.76	232	16.46	574	48.03	240	30.32	20	3.94	0	0.00	1.80	21	4000	13840	40380	25488
36	311.91	8356.4	80	270.24	128255	0	128255	5761	0	20	4.77	232	16.50	574	48.15	240	30.22	20	3.94	0	0.00	5.00	19	4000	13840	40380	25344
36	309.98	8360.8	80	102.96	126304	0	126304	5645	0	20	4.77	238	16.69	574	48.20	242	30.14	21	4.14	0	0.00	4.55	23	4000	13980	40380	25248
36	312.78	8373.6	80	56.35	124432	0	124432	5516	0	18	4.30	224	16.61	576	48.55	236	30.48	25	4.93	0	0.00	4.30	21	3600	13920	40680	25536
36	315.12	8362.8	80	175.33	124732	0	124732	5498	0	18	4.29	226	16.51	576	48.46	234	30.36	20	3.94	0	0.00	5.00	20	3600	13860	40680	25488
36	307.82	8364.0	80	35.37	124953	0	124953	5365	0	20	4.76	222	16.45	574	48.07	238	30.28	22	4.34	0	0.00	3.20	27	4000	13820	40380	25440
36*	315.31	8352.4	79	252.30	128157	0	128157	5840	0	20	4.79	228	16.52	574	48.35	240	30.34	18	3.55	0	0.00	3.15	22	4000	13800	40380	25344
36*	301.20	8338.0	80	150.88	122793	0	122793	5604	0	20	4.80	236	16.84	574	48.43	236	29.94	30	5.92	0	0.00	4.80	26	4000	14040	40380	24960
36*	308.97	8370.0	80	247.01	120140	0	120140	5410	0	20	4.78	236	16.58	574	48.24	241	30.39	19	3.75	0	0.00	3.60	25	4000	13880	40380	25440
36*	301.20	8356.0	80	195.70	123940	0	123940	5560	0	18	4.31	232	16.56	576	48.68	235	30.45	21	4.14	0	0.00	4.80	26	3600	13840	40680	25440
36*	313.64	8361.2	80	130.17	126427	0	126427	5712	0	18	4.31	226	16.39	576	48.65	237	30.66	15	2.96	0	0.00	3.10	19	3600	13700	40680	25632
36*	307.02	8358.4	80	189.63	124665	0	124665	5582	0	20	4.79	226	16.58	574	48.31	237	30.32	24	4.73	0	0.00	2.80	24	4000	13860	40380	25344
36*	300.92	8351.6	80	28.80	121207	0	121207	5346	0	20	4.79	232	16.57	574	48.35	241	30.29	16	3.16	0	0.00	3.45	19	4000	13840	40380	25296
36*	301.10	8362.4	80	10.45	122118	0	122118	5465	0	20	4.78	230	16.62	574	48.29	240	30.31	23	4.54	0	0.00	3.90	25	4000	13900	40380	25344
36*	309.97	8364.8	80	109.95	119879	0	119879	5448	0	20	4.78	234	16.47	574	48.27	243	30.47	22	4.34	0	0.00	3.65	18	4000	13780	40380	25488
36*	312.94	8366.8	80	235.31	122161	0	122161	5526	0	20	4.78	228	16.49	574	48.26	243	30.46	24	4.73	0	0.00	4.10	22	4000	13800	40380	25488

Table D.79: Results of all runs made with NSF network case 8, in 300 seconds.

COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
1	300.42	10143.6	80	216.93	8298	0	8298	3773	0	26	5.13	206	16.38	540	41.17	281	36.53	25	7.40	0	0.00	0.95	8	5200	16620	41760	37056
1	300.25	10084.4	80	114.32	8348	0	8348	3862	0	22	4.36	214	16.40	542	41.89	276	36.56	30	8.88	0	0.00	1.65	7	4400	16540	42240	36864
1	300.44	10155.2	80	290.30	8310	0	8310	3765	0	24	4.73	202	15.30	554	42.13	284	37.06	27	7.99	0	0.00	3.00	19	4800	15540	42780	37632
1	300.42	10087.6	80	0.64	8318	0	8318	3742	0	22	4.36	190	15.29	554	42.59	279	36.97	27	7.99	0	0.00	2.70	13	4400	15420	42960	37296
1	300.27	10191.2	80	211.68	8281	0	8281	3718	0	20	3.93	202	15.68	552	42.21	289	37.40	29	8.58	0	0.00	2.25	15	4000	15980	43020	38112
1	300.47	10078.4	80	160.09	8248	0	8248	3693	0	20	3.97	208	15.62	554	42.80	277	36.82	29	8.58	0	0.00	1.85	14	4000	15740	43140	37104
1	300.24	10138.8	80	203.47	8305	0	8305	3740	0	22	4.34	212	16.00	546	41.90	281	36.97	25	7.40	0	0.00	2.45	16	4400	16220	42480	37488
1	300.52	10156.0	80	240.58	8303	0	8303	3739	0	20	3.94	202	15.58	548	42.12	285	37.57	33	9.76	0	0.00	1.45	10	4000	15820	42780	38160
1	300.44	10132.4	80	262.69	8375	0	8375	3883	0	22	4.34	214	16.32	542	41.69	287	36.86	24	7.10	0	0.00	1.60	15	4400	16540	42240	37344
1	300.24	10221.2	80	195.53	8318	0	8318	3786	0	20	3.91	210	15.93	548	41.85	287	37.52	31	9.17	0	0.00	1.15	9	4000	16280	42780	38352
12	300.44	10087.2	80	1966.30	74700	0	74700	33615	0	20	3.97	200	15.52	556	42.89	279	36.83	27	7.99	0	0.00	3.15	22	4000	15660	43260	37152
12	300.44	10122.8	80	117.92	74538	0	74538	33542	0	22	4.35	210	15.87	550	42.20	277	36.80	30	8.88	0	0.00	2.60	11	4400	16060	42720	37248
12	300.25	10054.0	80	52.34	74556	0	74556	33550	0	26	5.17	200	15.20	552	42.25	295	38.19	26	7.69	0	0.00	1.90	12	5200	15280	42480	38400
12	300.33	10094.4	80	118.58	74682	0	74682	33607	0	26	5.15	206	15.34	546	41.73	287	36.99	32	9.47	1	0.39	1.75	11	5200	15480	42120	37344
12	300.42	10007.2	80	125.35	74853	0	74853	33684	0	30	6.00	216	16.57	542	41.67	289	38.08	33	9.76	0	0.00	3.95	23	6000	16580	41700	38112
12	300.22	10121.6	80	199.18	75123	0	75123	33805	0	16	3.16	198	15.37	554	42.62	279	37.56	30	8.88	0	0.00	1.55	17	3200	15560	43140	38016
12	300.35	9964.4	80	272.45	75150	0	75150	33818	0	26	5.22	214	16.92	540	41.73	289	37.96	28	8.28	0	0.00	4.10	28	5200	16860	41580	37824
12	300.41	10067.2	80	166.78	74592	0	74592	33566	0	30	5.96	208	17.05	536	41.42	297	40.48	24	7.10	0	0.00	4.55	33	6000	17160	41700	40752
12	300.25	10069.2	80	90.29	74313	0	74313	33441	0	26	5.16	204	16.03	542	41.59	274	36.42	26	7.69	0	0.00	2.45	16	5200	16140	41880	36672
12	300.24	10054.0	80	52.24	74574	0	74574	33558	0	26	5.17	200	15.20	552	42.25	295	38.19	26	7.69	0	0.00	1.90	12	5200	15280	42480	38400
36	300.44	10045.2	80	169.79	92030	0	92030	41414	0	20	3.98	186	14.93	560	43.30	282	36.98	26	7.69	1	0.39	3.75	29	4000	15000	43500	37152
36	300.41	10012.0	80	141.02	93206	0	93206	41943	0	22	4.39	192	15.34	556	43.03	272	36.44	22	6.51	0	0.00	1.20	7	4400	15360	43080	36480
36	300.49	10052.4	80	128.68	91564	0	91564	41204	0	22	4.38	204	15.90	546	42.26	279	36.67	20	5.92	0	0.00	2.05	11	4400	15980	42480	36864
36	300.22	10114.0	80	10.16	93304	0	93304	41987	0	16	3.16	202	14.83	566	43.72	284	37.49	25	7.40	0	0.00	2.15	9	3200	15000	44220	37920
36	300.24	9992.0	80	194.06	90514	0	90514	40731	0	22	4.40	202	15.29	554	42.99	278	36.51	25	7.40	0	0.00	2.00	18	4400	15280	42960	36480
36	300.27	10052.4	80	128.70	93251	0	93251	41963	0	22	4.38	204	15.90	546	42.26	279	36.67	20	5.92	0	0.00	2.05	11	4400	15980	42480	36864
36	300.41	10088.0	80	247.76	91267	0	91267	41070	0	24	4.76	214	16.24	540	41.57	283	36.64	27	7.99	0	0.00	1.95	9	4800	16380	41940	36960
36	300.44	10093.6	80	144.18	92385	0	92385	41573	0	24	4.76	204	15.71	552	42.26	280	36.47	33	9.76	0	0.00	1.50	9	4800	15860	42660	36816
36	300.27	10016.4	80	163.52	92774	0	92774	41748	0	26	5.19	194	15.43	558	43.13	305	40.88	27	7.99	0	0.00	1.55	12	5200	15460	43200	40944
36	300.53	10086.8	80	90.53	93428	0	93428	42043	0	20	3.97	208	16.26	546	42.29	279	36.69	30	8.88	0	0.00	1.00	5	4000	16400	42660	37008
36*	300.25	10073.2	80	118.14	86902	0	86902	39106	0	20	3.97	212	16.48	546	42.35	274	36.41	22	6.51	0	0.00	2.30	12	4000	16600	42660	36672
36*	300.42	10048.8	80	281.72	87024	0	87024	39161	0	22	4.38	190	15.13	560	43.11	272	36.59	31	9.17	0	0.00	1.70	11	4400	15200	43320	36768
36*	300.52	10001.2	80	178.78	88213	0	88213	39696	0	24	4.80	198	15.56	552	42.65	278	36.19	37	10.95	0	0.00	3.10	19	4800	15560	42660	36192
36*	300.25	10060.0	80	88.73	85583	0	85583	38512	0	18	3.58	196	14.99	560	43.42	282	37.22	26	7.69	0	0.00	0.80	6	3600	15080	43680	37440
36*	300.39	10024.0	80	287.71	89683	0	89683	40357	0	20	3.99	196	14.29	566	43.76	297	38.79	22	6.51	0	0.00	1.90	12	4000	14320	43860	38880
36*	300.44	9470.4	80	285.73	88213	0	88213	39696	0	26	5.49	188	15.14	568	45.87	286	39.94	29	8.58	0	0.00	4.75	40	5200	14340	43440	37824
36*	300.22	9980.0	80	139.35	88735	0	88735	39931	0	28	5.61	202	16.01	536	40.88	290	37.27	21	6.21	0	0.00	2.80	19	5600	15980	40800	37200
36*	300.41	10089.6	80	260.38	90230	0	90230	40604	0	22	4.36	198	15.42	552	42.46	285	36.96	28	8.28	0	0.00	2.90	14	4400	15560	42840	37296
36*	300.28	10072.8	80	291.56	92241	0	92241	41508	0	20	3.97	190	14.71	566	43.54	280	36.98	31	9.17	0	0.00	1.05	5	4000	14820	43860	37248
36*	300.42	10104.0	80	241.80	91037	0	91037	40967	0	26	5.15	208	15.68	552	42.04	282	36.34	34	10.06	0	0.00	1.30	10	5200	15840	42480	36720

Table D.80: Results of all runs made with NSF network case 9, in 300 seconds.

Appendix E

Compact Results

E.1 GEANT2 best results for 60 seconds.

Symbol	Name
$\#T$	Number of Threads
t_E	Time of Execution
C	Best Cost Solution found
CA	Highest Channel Assigned
t_{sol}	Found Solution Time
$\#i$	Number of Iterations
$\#IS$	Number of Invalid Solutions
$\#G_U$	Number of Greedy Solutions Unfeasible
$\#LS_U$	Number of Local Search Solutions Unfeasible
UD	Unfeasible Degree
$\#IM$	Number of Invert Multiplex used
C_{IM}	Cost % of Invert Multiplex
$\#MX$	Number of Muxponders placed
C_{MX}	Cost % of Muxponders
$\#TX$	Number of Transponders placed
C_{TX}	Cost % of Transponders
$\#3R$	Number of $3R$ regenerators placed
C_{3R}	Cost % of $3R$ regenerators
#10	Number of Multi-Hop Grooming of $10Gb/s$
%10	Traffic % of Multi-Hop Grooming of $10Gb/s$
#40	Number of Multi-hop Grooming of $40Gb/s$
%40	Traffic % of Multi-hop Grooming of $40Gb/s$
$\bar{m}F$	Average Fragmentation at Channel Assigned
MF	Max Fragmentation at Channel Assigned
C_{IM}	Cost of Invert Multiplexers
C_{MX}	Cost of Multiplexers
C_{TX}	Cost of Transponders
C_{3R}	Cost of $3R$ regenerators

Table E.1: Header symbols and their description.

OPERATIONS	COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
	$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	#10G	%10G	#40G	%40G	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
Case 1																												
Mean	1	60.81	7720.40	63.20	25.93	157.80	0.00	0.00	0.00	0.00	13.60	3.52	537.60	37.68	300.40	30.39	199.70	28.41	58.80	5.880	0.00	0.00	12.75	43.90	2720.00	29088.00	23460.00	21936.00
Min	1	60.64	7660.80	64.00	3.65	160.00	0.00	0.00	0.00	0.00	16.00	4.18	530.00	37.72	298.00	30.15	196.00	27.94	61.00	6.100	0.00	0.00	13.62	45.00	3200.00	28900.00	23100.00	21408.00
Max	1	60.86	7754.00	61.00	10.58	162.00	0.00	0.00	0.00	0.00	14.00	3.61	534.00	37.74	300.00	30.18	200.00	28.48	47.00	4.700	0.00	0.00	12.44	40.00	2800.00	29260.00	23400.00	22080.00
Mean	12	61.26	7688.44	63.40	29.41	1672.70	0.00	0.00	0.00	0.00	14.40	3.73	535.40	37.70	299.60	30.22	197.10	27.89	60.30	6.030	0.00	0.00	12.82	44.50	2880.00	29122.00	23340.00	21542.40
Min	12	61.42	7588.00	63.00	6.79	1644.00	0.00	0.00	0.00	0.00	14.00	3.61	536.00	37.42	300.00	30.15	188.00	26.60	59.00	5.900	0.00	0.00	13.46	46.00	2800.00	29040.00	23400.00	20640.00
Max	12	60.78	7724.40	61.00	45.88	1652.00	0.00	0.00	0.00	0.00	14.00	3.62	530.00	37.58	300.00	30.26	199.00	28.43	58.00	5.800	0.00	0.00	12.33	42.00	2800.00	29060.00	23400.00	21984.00
Mean	36	72.73	7688.36	64.00	31.49	2016.20	0.00	0.00	0.00	0.00	16.00	4.12	534.20	37.50	298.00	29.72	197.40	27.59	59.80	5.980	0.00	0.00	12.98	45.80	3200.00	29142.00	23100.00	21441.60
Min	36	73.54	7662.40	66.00	47.19	1862.00	0.00	0.00	0.00	0.00	16.00	4.11	522.00	37.01	298.00	29.67	197.00	27.62	54.00	5.400	0.00	0.00	13.08	48.00	3200.00	28820.00	23100.00	21504.00
Max	36	67.47	7704.40	65.00	19.03	1930.00	0.00	0.00	0.00	0.00	20.00	5.15	536.00	38.04	294.00	28.99	195.00	27.09	69.00	6.900	0.00	0.00	13.44	47.00	4000.00	29520.00	22500.00	21024.00
Mean	36*	61.85	7682.96	63.70	35.36	1729.30	0.00	0.00	0.00	0.00	15.20	3.96	534.40	37.69	298.80	30.22	198.40	28.13	56.50	5.650	0.00	0.00	12.91	44.70	3040.00	28960.00	23220.00	21609.60
Min	36*	62.03	7588.00	63.00	27.30	1744.00	0.00	0.00	0.00	0.00	14.00	3.69	536.00	38.27	300.00	30.84	188.00	27.20	59.00	5.900	0.00	0.00	13.46	46.00	2800.00	29040.00	23400.00	20640.00
Max	36*	62.01	7726.40	62.00	16.55	1734.00	0.00	0.00	0.00	0.00	12.00	3.11	534.00	37.46	302.00	30.67	200.00	28.76	60.00	6.000	0.00	0.00	12.65	43.00	2400.00	28940.00	23700.00	22224.00
Case 2																												
Mean	1	60.85	8022.04	78.70	33.88	163.20	0.00	125.60	0.00	0.00	10.60	2.64	323.40	20.65	558.60	48.89	208.70	27.81	51.00	10.200	0.00	0.00	18.07	60.90	2120.00	16568.00	39222.00	22310.40
Min	1	60.59	8001.60	78.00	53.73	160.00	0.00	119.00	0.00	0.00	8.00	2.00	332.00	21.02	562.00	49.57	203.00	27.41	56.00	11.200	0.00	0.00	16.46	62.00	1600.00	16820.00	39660.00	21936.00
Max	1	60.93	8052.00	80.00	16.35	163.00	0.00	118.00	0.00	0.00	12.00	2.98	314.00	19.90	562.00	48.81	212.00	28.32	51.00	10.200	0.00	0.00	17.29	61.00	2400.00	16020.00	39300.00	22800.00
Mean	12	61.06	7964.68	78.40	29.72	1764.50	0.00	1345.40	0.00	0.00	9.40	2.35	320.60	20.46	560.60	49.22	203.10	27.34	52.80	10.560	0.00	0.00	17.85	58.40	1880.00	16400.00	39450.00	21916.80
Min	12	60.75	7926.00	79.00	50.83	1686.00	0.00	1302.00	0.00	0.00	10.00	2.51	320.00	20.89	554.00	48.90	201.00	27.08	50.00	10.000	0.00	0.00	18.87	62.00	2000.00	16660.00	39000.00	21600.00
Max	12	61.37	7977.20	79.00	36.74	1802.00	0.00	1368.00	0.00	0.00	10.00	2.49	318.00	19.79	564.00	49.28	208.00	27.72	53.00	10.600	0.00	0.00	17.62	49.00	2000.00	15900.00	39600.00	22272.00
Mean	36	71.92	7960.32	78.60	30.26	2109.10	0.00	1614.60	0.00	0.00	10.80	2.68	323.80	20.54	558.00	48.66	204.40	27.01	51.90	10.380	0.00	0.00	18.44	58.70	2160.00	16536.00	39168.00	21739.20
Min	36	76.16	7912.80	80.00	17.94	2182.00	0.00	1681.00	0.00	0.00	10.00	2.48	326.00	21.02	554.00	48.34	198.00	26.24	57.00	11.400	0.00	0.00	18.81	56.00	2000.00	16960.00	39000.00	21168.00
Max	36	72.24	7986.00	80.00	8.21	2122.00	0.00	1605.00	0.00	0.00	12.00	2.99	322.00	21.10	552.00	48.27	205.00	27.24	49.00	9.800	0.00	0.00	18.88	56.00	2400.00	16920.00	38700.00	21840.00
Mean	36*	61.72	7971.40	78.90	34.06	1771.10	0.00	1360.50	0.00	0.00	12.40	3.11	323.60	20.93	555.60	48.77	203.70	27.19	52.40	10.480	0.00	0.00	18.14	59.60	2480.00	16682.00	38880.00	21672.00
Min	36*	61.90	7920.40	78.00	53.23	1820.00	0.00	1410.00	0.00	0.00	14.00	3.54	328.00	20.98	556.00	48.94	198.00	26.54	62.00	12.400	0.00	0.00	18.77	55.00	2800.00	16620.00	38760.00	21024.00
Max	36*	61.95	7996.40	80.00	9.27	1779.00	0.00	1368.00	0.00	0.00	12.00	3.00	318.00	20.36	558.00	48.85	209.00	27.79	53.00	10.600	0.00	0.00	18.96	64.00	2400.00	16280.00	39060.00	22224.00
Case 3																												
Mean	1	60.86	8882.36	79.50	31.79	160.20	0.00	156.80	0.00	0.00	35.80	8.06	275.60	15.55	598.20	50.36	210.10	26.03	57.70	14.425	0.00	0.00	17.13	64.80	7160.00	13812.00	44730.00	23121.60
Min	1	60.50	8859.20	80.00	57.31	157.00	0.00	155.00	0.00	0.00	36.00	8.13	274.00	15.46	598.00	50.46	208.00	25.95	61.00	15.250	0.00	0.00	17.69	64.00	7200.00	13700.00	44700.00	22992.00
Max	1	60.62	8916.80	80.00	8.14	158.00	0.00	154.00	0.00	0.00	32.00	7.18	278.00	15.59	602.00	50.80	211.00	26.43	50.00	12.500	0.00	0.00	17.46	64.00	6400.00	13900.00	45300.00	23568.00
Mean	12	61.12	8820.24	79.30	37.90	1725.80	0.00	1692.90	0.00	0.00	36.40	8.22	273.20	15.42	597.60	50.38	204.00	25.53	55.60	13.900	0.00	0.00	17.66	64.60	7280.00	13660.00	44640.00	22622.40
Min	12	61.21	8777.20	79.00	23.84	1745.00	0.00	1697.00	0.00	0.00	36.00	8.14	272.00	15.38	598.00	50.57	199.00	25.19	55.00	13.750	0.00	0.00	18.42	63.00	7200.00	13600.00	44700.00	22272.00
Max	12	60.96	8844.80	80.00	33.77	1668.00	0.00	1636.00	0.00	0.00	36.00	8.10	274.00	15.42	598.00	50.31	205.00	25.71	53.00	13.250	0.00	0.00	17.35	68.00	7200.00	13700.00	44700.00	22848.00
Mean	36	71.73	8825.44	79.10	30.87	2047.50	0.00	2006.80	0.00	0.00	36.20	8.13	274.60	15.44	597.80	50.16	204.20	25.38	57.10	14.275	0.00	0.00	17.48	64.50	7240.00	13746.00	44670.00	22598.40
Min	36	68.42	8806.00	79.00	23.93	1972.00	0.00	1935.00	0.00	0.00	36.00	8.09	272.00	15.28	598.00	50.23	202.00	25.35	55.00	13.750	0.00	0.00	19.31	67.00	7200.00	13600.00	44700.00	22560.00
Max	36	67.20	8844.80	80.00	34.01	1947.00	0.00	1910.00	0.00	0.00	32.00	7.21	278.00	15.65	602.00	51.01	205.00	25.73	61.00	15.250	0.00	0.00	18.85	64.00	6400.00	13900.00	45300.00	22848.00
Mean	36*	62.69	8830.04	79.10	29.33	1768.00	0.00	1733.30	0.00	0.00	34.80	7.88	275.80	15.62	599.20	50.83	203.90	25.67	55.10	13.775	0.00	0.00	17.04	62.60	6960.00	13790.00	44880.00	22670.40
Min	36*	61.84	8793.20	80.00	44.60	1763.00	0.00	1735.00	0.00	0.00	40.00	9.10	276.00	15.69	594.00	50.15	201.00	25.06	53.00	13.250	0.00	0.00	17.87	67.00	8000.00	13800.00	44100.00	22032.00
Max	36*	61.60	8859.60	78.00	27.96	1771.00	0.00	1731.00	0.00	0.00	34.00	7.68	278.00	15.69	600.00	50.79	207.00	25.84	55.00	13.750	0.00	0.00	17.15	66.00	6800.00	13900.00	45000.00	22896.00

Table E.2: Results of the best results of GEANT2 network cases 1, 2 and 3, for 60 seconds.

OPERATIONS	COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
	$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
Case 4																												
Mean	1	61.49	9678.40	80.00	29.82	44.60	0.00	44.60	0.00	0.00	21.60	4.46	668.60	36.38	340.00	27.07	281.80	32.09	99.70	8.670	0.00	0.00	17.49	56.70	4320.00	35212.00	26196.00	31056.00
Min	1	61.71	9551.60	80.00	41.15	44.00	0.00	44.00	0.00	0.00	24.00	5.03	660.00	36.39	338.00	27.07	279.00	31.51	96.00	8.348	0.00	0.00	18.35	57.00	4800.00	34760.00	25860.00	30096.00
Max	1	62.04	9770.80	80.00	57.11	46.00	0.00	46.00	0.00	0.00	24.00	4.91	660.00	35.90	338.00	26.47	285.00	32.72	92.00	8.000	0.00	0.00	17.40	56.00	4800.00	35080.00	25860.00	31968.00
Mean	12	62.34	9619.16	80.00	30.05	485.80	0.00	485.80	0.00	0.00	19.60	4.04	673.00	36.41	341.60	27.26	274.50	31.35	101.10	8.791	0.00	0.00	17.56	57.80	3920.00	35358.00	26472.00	30441.60
Min	12	62.52	9580.00	80.00	23.93	477.00	0.00	477.00	0.00	0.00	20.00	4.12	654.00	36.16	342.00	27.26	267.00	31.15	101.00	8.783	0.00	0.00	17.88	60.00	4000.00	35100.00	26460.00	30240.00
Max	12	62.26	9661.20	80.00	35.69	481.00	0.00	481.00	0.00	0.00	16.00	3.27	666.00	36.26	342.00	27.44	278.00	31.87	98.00	8.522	0.00	0.00	16.73	54.00	3200.00	35440.00	26820.00	31152.00
Mean	36	73.68	9593.72	80.00	31.37	576.30	0.00	576.10	0.00	0.00	20.20	4.14	667.40	36.02	341.40	27.07	274.20	31.12	96.50	8.391	0.00	0.00	17.42	57.10	4040.00	35136.00	26406.00	30355.20
Min	36	73.79	9523.20	80.00	3.87	582.00	0.00	582.00	0.00	0.00	20.00	4.10	658.00	35.68	342.00	27.12	276.00	30.69	97.00	8.435	0.00	0.00	17.92	55.00	4000.00	34820.00	26460.00	29952.00
Max	36	73.34	9644.40	80.00	11.09	578.00	0.00	578.00	0.00	0.00	18.00	3.73	658.00	36.26	344.00	27.74	276.00	32.24	95.00	8.261	0.00	0.00	16.67	59.00	3600.00	34980.00	26760.00	31104.00
Mean	36*	63.97	9600.36	80.00	26.12	499.10	0.00	498.80	0.00	0.00	18.60	3.88	668.00	36.64	342.60	27.73	274.40	31.76	99.80	8.678	0.00	0.00	17.58	56.70	3720.00	35172.00	26622.00	30489.60
Min	36*	63.76	9523.20	80.00	3.74	507.00	0.00	507.00	0.00	0.00	20.00	4.20	658.00	36.56	342.00	27.78	276.00	31.45	97.00	8.435	0.00	0.00	17.92	55.00	4000.00	34820.00	26460.00	29952.00
Max	36*	64.27	9676.80	80.00	41.10	504.00	0.00	503.00	0.00	0.00	16.00	3.31	670.00	36.44	346.00	27.96	279.00	32.29	93.00	8.087	0.00	0.00	16.12	55.00	3200.00	35260.00	27060.00	31248.00
Case 5																												
Mean	1	61.24	9339.64	79.50	26.11	68.90	0.00	68.60	0.00	0.00	28.80	6.17	398.00	21.42	632.80	46.16	230.80	26.25	90.70	15.774	0.00	0.00	15.53	56.00	5760.00	20002.00	43116.00	24518.40
Min	1	61.37	9281.20	80.00	50.65	69.00	0.00	69.00	0.00	0.00	32.00	6.90	396.00	21.33	630.00	45.96	230.00	25.81	96.00	16.696	0.00	0.00	16.48	57.00	6400.00	19800.00	42660.00	23952.00
Max	1	61.32	9378.80	78.00	24.30	66.00	0.00	65.00	0.00	0.00	30.00	6.40	398.00	21.39	632.00	45.81	237.00	26.41	84.00	14.609	0.00	0.00	14.56	56.00	6000.00	20060.00	42960.00	24768.00
Mean	12	61.86	9293.08	79.40	35.73	739.10	0.00	737.20	0.00	0.00	28.40	6.08	396.20	21.29	632.80	46.17	227.00	25.89	92.00	16.000	0.00	0.00	15.78	58.80	5680.00	19902.00	43152.00	24196.80
Min	12	61.62	9240.80	78.00	48.70	740.00	0.00	737.00	0.00	0.00	30.00	6.41	388.00	20.72	632.00	45.88	225.00	25.68	90.00	15.652	0.00	0.00	15.19	57.00	6000.00	19400.00	42960.00	24048.00
Max	12	62.26	9327.60	79.00	58.23	738.00	0.00	736.00	0.00	0.00	24.00	5.13	396.00	21.14	638.00	46.84	230.00	26.50	84.00	14.609	0.00	0.00	14.94	54.00	4800.00	19800.00	43860.00	24816.00
Mean	36	73.88	9267.08	79.00	42.96	887.40	0.00	883.90	0.00	0.00	29.80	6.35	396.60	21.19	631.80	45.79	225.90	25.43	92.00	16.000	0.00	0.00	15.58	54.80	5960.00	19884.00	42966.00	23860.80
Min	36	67.75	9240.80	78.00	50.56	810.00	0.00	805.00	0.00	0.00	30.00	6.38	388.00	20.63	632.00	45.69	225.00	25.58	90.00	15.652	0.00	0.00	15.19	57.00	6000.00	19400.00	42960.00	24048.00
Max	36	67.78	9308.00	80.00	8.24	810.00	0.00	806.00	0.00	0.00	28.00	5.98	400.00	21.58	630.00	45.92	227.00	25.87	87.00	15.130	0.00	0.00	15.38	52.00	5600.00	20220.00	43020.00	24240.00
Mean	36*	63.05	9293.32	79.20	33.05	745.50	0.00	742.30	0.00	0.00	29.00	6.24	397.40	21.42	632.60	46.36	227.30	25.97	93.30	16.226	0.00	0.00	16.18	56.30	5800.00	19908.00	43086.00	24139.20
Min	36*	63.32	9251.60	80.00	52.92	748.00	0.00	741.00	0.00	0.00	28.00	6.05	396.00	21.40	634.00	46.76	223.00	25.79	89.00	15.478	0.00	0.00	16.27	57.00	5600.00	19800.00	43260.00	23856.00
Max	36*	62.51	9321.20	80.00	12.92	751.00	0.00	749.00	0.00	0.00	34.00	7.30	402.00	21.56	628.00	45.44	230.00	25.70	100.00	17.391	0.00	0.00	17.31	56.00	6800.00	20100.00	42360.00	23952.00
Case 6																												
Mean	1	61.32	10264.96	79.60	27.80	66.40	0.00	66.30	0.00	0.00	36.40	7.09	338.60	16.76	691.20	50.89	229.60	25.26	87.30	18.978	0.00	0.00	18.17	63.00	7280.00	17204.00	52236.00	25929.60
Min	1	60.92	10227.60	77.00	51.92	65.00	0.00	65.00	0.00	0.00	36.00	7.04	332.00	16.60	692.00	51.16	228.00	25.20	88.00	19.130	0.00	0.00	17.42	61.00	7200.00	16980.00	52320.00	25776.00
Max	1	60.76	10322.80	80.00	9.89	67.00	0.00	67.00	0.00	0.00	38.00	7.36	344.00	17.09	686.00	50.16	234.00	25.39	81.00	17.609	0.00	0.00	17.88	67.00	7600.00	17640.00	51780.00	26208.00
Mean	12	61.81	10231.80	79.80	23.44	699.70	0.00	698.60	0.00	0.00	37.60	7.31	336.80	16.57	690.80	50.67	228.40	24.95	90.40	19.652	0.00	0.00	18.03	63.60	7520.00	17038.00	52104.00	25656.00
Min	12	62.24	10190.80	80.00	4.96	692.00	0.00	690.00	0.00	0.00	38.00	7.42	336.00	16.39	694.00	50.99	224.00	24.64	105.00	22.826	0.00	0.00	17.73	60.00	7600.00	16800.00	52260.00	25248.00
Max	12	61.98	10252.80	80.00	58.34	693.00	0.00	692.00	0.00	0.00	40.00	7.76	342.00	16.79	688.00	50.15	228.00	24.71	89.00	19.348	0.00	0.00	17.27	66.00	8000.00	17320.00	51720.00	25488.00
Mean	36	71.70	10212.80	79.70	30.07	817.40	0.00	815.60	0.00	0.00	37.00	7.17	336.80	16.60	689.80	50.46	225.90	24.69	90.50	19.674	0.00	0.00	18.80	60.60	7400.00	17142.00	52098.00	25488.00
Min	36	74.35	10171.20	80.00	1.64	845.00	0.00	843.00	0.00	0.00	34.00	6.57	334.00	16.56	690.00	50.61	221.00	24.54	104.00	22.609	0.00	0.00	19.27	60.00	6800.00	17140.00	52380.00	25392.00
Max	36	67.97	10250.40	78.00	33.31	773.00	0.00	772.00	0.00	0.00	34.00	6.57	336.00	16.45	694.00	50.86	231.00	25.19	85.00	18.478	0.00	0.00	18.17	57.00	6800.00	17020.00	52620.00	26064.00
Mean	36*	64.39	10210.60	79.90	17.75	717.10	0.00	715.90	0.00	0.00	38.20	7.48	334.00	16.54	690.60	50.97	228.20	25.01	92.80	20.174	0.00	0.00	18.98	62.70	7640.00	16892.00	52038.00	25536.00
Min	36*	63.23	10156.80	80.00	36.32	708.00	0.00	708.00	0.00	0.00	38.00	7.48	326.00	16.21	694.00	51.45	227.00	24.86	88.00	19.130	0.00	0.00	18.44	64.00	7600.00	16460.00	52260.00	25248.00
Max	36*	62.88	10256.00	80.00	30.05	719.00	0.00	716.00	0.00	0.00	42.00	8.19	332.00	16.40	686.00	50.14	234.00	25.27	86.00	18.696	0.00	0.00	18.04	66.00	8400.00	16820.00	51420.00	25920.00

Table E.3: Results of the best results of GEANT2 network cases 4, 5 and 6, for 60 seconds.

OPERATIONS	COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
	$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
Case 7																												
Mean	1	62.11	10639.20	80.00	25.76	31.50	0.00	31.50	0.00	0.00	17.40	3.27	792.60	38.70	389.40	28.95	288.80	29.08	122.30	9.244	0.00	0.00	15.16	54.80	3480.00	41178.00	30798.00	30936.00
Min	1	62.49	10563.20	80.00	58.00	33.00	0.00	33.00	0.00	0.00	18.00	3.41	792.00	38.76	392.00	29.25	286.00	28.58	136.00	10.280	0.00	0.00	15.75	55.00	3600.00	40940.00	30900.00	30192.00
Max	1	62.93	10688.80	80.00	2.01	32.00	0.00	32.00	0.00	0.00	16.00	2.99	784.00	38.13	390.00	28.96	297.00	29.91	120.00	9.070	0.00	0.00	14.02	54.00	3200.00	40760.00	30960.00	31968.00
Mean	12	63.27	10567.72	80.00	30.42	324.50	0.00	323.90	0.00	0.00	15.40	2.88	789.60	38.19	393.80	29.26	283.80	28.63	122.00	9.221	0.00	0.00	15.24	54.90	3080.00	40784.00	31242.00	30571.20
Min	12	63.12	10501.60	80.00	11.83	327.00	0.00	327.00	0.00	0.00	14.00	2.62	774.00	37.59	400.00	29.72	280.00	28.41	121.00	9.146	0.00	0.00	15.65	52.00	2800.00	40140.00	31740.00	30336.00
Max	12	63.32	10629.60	80.00	55.68	333.00	0.00	331.00	0.00	0.00	14.00	2.62	800.00	38.12	396.00	29.50	293.00	29.31	118.00	8.919	0.00	0.00	14.73	60.00	2800.00	40700.00	31500.00	31296.00
Mean	36	74.62	10562.32	79.80	38.48	386.30	0.00	386.00	0.00	0.00	17.20	3.20	788.20	38.03	390.00	28.68	283.50	28.29	122.20	9.237	0.00	0.00	15.19	55.70	3440.00	40904.00	30852.00	30427.20
Min	36	78.90	10504.80	80.00	55.44	406.00	0.00	406.00	0.00	0.00	18.00	3.36	790.00	38.08	388.00	28.66	283.00	28.08	119.00	8.995	0.00	0.00	16.67	56.00	3600.00	40740.00	30660.00	30048.00
Max	36	73.96	10601.20	80.00	2.61	389.00	0.00	389.00	0.00	0.00	12.00	2.22	796.00	37.60	398.00	29.41	287.00	28.81	116.00	8.768	0.00	0.00	14.19	59.00	2400.00	40660.00	31800.00	31152.00
Mean	36*	65.30	10547.04	80.00	38.27	341.50	0.00	341.20	0.00	0.00	16.60	3.15	785.00	38.40	394.20	29.54	284.80	28.91	120.20	9.085	0.00	0.00	15.12	54.60	3320.00	40498.00	31158.00	30494.40
Min	36*	64.27	10471.20	80.00	36.66	340.00	0.00	340.00	0.00	0.00	20.00	3.82	780.00	38.58	386.00	28.99	282.00	28.60	134.00	10.128	0.00	0.00	15.54	53.00	4000.00	40400.00	30360.00	29952.00
Max	36*	65.93	10578.00	80.00	20.34	334.00	0.00	333.00	0.00	0.00	18.00	3.40	786.00	38.57	392.00	29.21	286.00	28.81	118.00	8.919	0.00	0.00	15.56	57.00	3600.00	40800.00	30900.00	30480.00
Case 8																												
Mean	1	62.18	11073.64	79.60	32.45	29.30	0.00	29.30	0.00	0.00	35.20	6.36	477.60	21.93	722.80	44.43	289.60	27.28	132.30	19.985	0.00	0.00	16.27	58.10	7040.00	24290.00	49200.00	30206.40
Min	1	62.46	10975.20	80.00	42.18	29.00	0.00	29.00	0.00	0.00	34.00	6.20	472.00	21.85	726.00	45.10	280.00	26.85	127.00	19.184	0.00	0.00	16.98	68.00	6800.00	23980.00	49500.00	29472.00
Max	1	61.84	11182.80	80.00	2.39	28.00	0.00	28.00	0.00	0.00	36.00	6.44	490.00	22.70	712.00	43.35	295.00	27.51	141.00	21.299	0.00	0.00	16.83	49.00	7200.00	25380.00	48480.00	30768.00
Mean	12	63.20	10988.76	80.00	37.19	281.00	0.00	280.90	0.00	0.00	35.20	6.35	471.60	21.45	726.00	44.55	284.50	26.76	127.50	19.260	0.00	0.00	17.03	58.60	7040.00	23782.00	49392.00	29673.60
Min	12	62.95	10905.60	80.00	49.06	286.00	0.00	286.00	0.00	0.00	40.00	7.21	472.00	21.65	716.00	43.56	279.00	25.81	117.00	17.674	0.00	0.00	16.10	55.00	8000.00	24040.00	48360.00	28656.00
Max	12	63.69	11033.20	80.00	9.30	279.00	0.00	279.00	0.00	0.00	36.00	6.51	470.00	21.23	728.00	44.67	289.00	27.28	131.00	19.789	0.00	0.00	17.79	52.00	7200.00	23500.00	49440.00	30192.00
Mean	36	75.25	10988.84	79.60	43.16	335.90	0.00	335.90	0.00	0.00	34.00	6.08	472.80	21.38	726.40	44.25	282.40	26.48	126.80	19.154	0.00	0.00	17.13	55.10	6800.00	23934.00	49524.00	29630.40
Min	36	74.30	10933.60	80.00	24.07	331.00	0.00	331.00	0.00	0.00	38.00	6.75	476.00	21.46	722.00	43.40	276.00	25.43	125.00	18.882	0.00	0.00	17.63	64.00	7600.00	24180.00	48900.00	28656.00
Max	36	72.68	11034.40	79.00	19.72	323.00	0.00	323.00	0.00	0.00	36.00	6.43	468.00	21.03	728.00	44.14	290.00	26.91	126.00	19.033	0.00	0.00	16.44	47.00	7200.00	23560.00	49440.00	30144.00
Mean	36*	67.21	11000.60	79.60	37.10	293.20	0.00	293.20	0.00	0.00	34.60	6.29	474.00	21.76	726.20	44.96	284.80	26.99	127.60	19.275	0.00	0.00	17.28	55.00	6920.00	23940.00	49458.00	29688.00
Min	36*	65.05	10962.80	80.00	60.26	286.00	0.00	286.00	0.00	0.00	36.00	6.57	470.00	21.58	728.00	45.10	283.00	26.75	121.00	18.278	0.00	0.00	18.13	64.00	7200.00	23660.00	49440.00	29328.00
Max	36*	69.34	11036.40	80.00	50.06	298.00	0.00	298.00	0.00	0.00	36.00	6.52	478.00	22.45	712.00	43.93	286.00	27.10	133.00	20.091	0.00	0.00	15.37	51.00	7200.00	24780.00	48480.00	29904.00
Case 9																												
Mean	1	61.57	12751.20	80.00	22.68	32.30	0.00	32.30	0.00	0.00	45.00	7.06	404.00	16.36	789.00	46.66	339.30	29.92	115.60	21.853	0.00	0.00	15.03	54.10	9000.00	20862.00	59490.00	38160.00
Min	1	60.64	12614.40	80.00	19.41	33.00	0.00	33.00	0.00	0.00	48.00	7.61	392.00	15.89	788.00	46.90	338.00	29.60	109.00	20.605	0.00	0.00	15.04	53.00	9600.00	20040.00	59160.00	37344.00
Max	1	61.76	12895.60	80.00	15.94	34.00	0.00	34.00	0.00	0.00	48.00	7.44	402.00	15.71	796.00	46.25	360.00	30.60	110.00	20.794	0.00	0.00	15.69	51.00	9600.00	20260.00	59640.00	39456.00
Mean	12	62.91	12634.64	80.00	30.74	327.10	0.00	327.10	0.00	0.00	46.40	7.26	403.80	16.59	782.80	46.17	328.80	28.86	117.40	22.193	0.00	0.00	14.65	56.90	9280.00	21196.00	58992.00	36878.40
Min	12	62.49	12459.60	80.00	26.83	330.00	0.00	330.00	0.00	0.00	48.00	7.48	398.00	16.31	780.00	45.70	316.00	27.55	113.00	21.361	0.00	0.00	15.02	57.00	9600.00	20940.00	58680.00	35376.00
Max	12	62.65	12714.00	80.00	51.70	330.00	0.00	330.00	0.00	0.00	50.00	7.85	406.00	16.93	774.00	45.64	339.00	29.39	112.00	21.172	0.00	0.00	14.15	61.00	10000.00	21560.00	58140.00	37440.00
Mean	36	79.29	12642.48	80.00	35.60	402.10	0.00	402.10	0.20	0.00	46.20	7.19	403.60	16.25	787.00	46.12	329.70	28.82	118.10	22.325	0.00	0.00	14.28	53.50	9240.00	20886.00	59262.00	37036.80
Min	36	74.61	12556.00	80.00	8.36	382.00	0.00	382.00	1.00	0.00	44.00	6.81	406.00	15.87	796.00	46.41	322.00	28.03	115.00	21.739	0.00	0.00	14.10	50.00	8800.00	20520.00	60000.00	36240.00
Max	36	74.85	12725.60	80.00	31.87	387.00	0.00	387.00	0.00	0.00	50.00	7.76	404.00	16.19	782.00	45.51	335.00	29.33	124.00	23.440	0.00	0.00	14.02	51.00	10000.00	20860.00	58620.00	37776.00
Mean	36*	65.50	12635.80	80.00	26.08	335.90	0.00	335.90	0.10	0.00	47.20	7.47	407.20	16.67	785.20	46.74	330.60	29.12	115.80	21.890	0.00	0.00	14.47	54.70	9440.00	21062.00	59064.00	36792.00
Min	36*	65.64	12553.60	80.00	9.41	333.00	0.00	333.00	0.00	0.00	50.00	7.97	410.00	17.16	778.00	46.50	326.00	28.37	123.00	23.251	0.00	0.00	15.19	55.00	10000.00	21540.00	58380.00	35616.00
Max	36*	65.30	12696.80	80.00	27.43	338.00	0.00	338.00	0.00	0.00	46.00	7.25	406.00	17.15	774.00	46.07	338.00	29.53	109.00	20.605	0.00	0.00	14.44	57.00	9200.00	21780.00	58500.00	37488.00

Table E.4: Results of the best results of GEANT2 network cases 7, 8 and 9, for 60 seconds.

E.2 EON best results for 60 seconds.

Symbol	Name
$\#T$	Number of Threads
t_E	Time of Execution
C	Best Cost Solution found
CA	Highest Channel Assigned
t_{sol}	Found Solution Time
$\#i$	Number of Iterations
$\#IS$	Number of Invalid Solutions
$\#G_U$	Number of Greedy Solutions Unfeasible
$\#LS_U$	Number of Local Search Solutions Unfeasible
UD	Unfeasible Degree
$\#IM$	Number of Invert Multiplex used
C_{IM}	Cost % of Invert Multiplex
$\#MX$	Number of Muxponders placed
C_{MX}	Cost % of Muxponders
$\#TX$	Number of Transponders placed
C_{TX}	Cost % of Transponders
$\#3R$	Number of $3R$ regenerators placed
C_{3R}	Cost % of $3R$ regenerators
$\#10$	Number of Multi-Hop Grooming of $10Gb/s$
$\%10$	Traffic % of Multi-Hop Grooming of $10Gb/s$
$\#40$	Number of Multi-hop Grooming of $40Gb/s$
$\%40$	Traffic % of Multi-hop Grooming of $40Gb/s$
$\bar{m}F$	Average Fragmentation at Channel Assigned
MF	Max Fragmentation at Channel Assigned
C_{IM}	Cost of Invert Multiplexers
C_{MX}	Cost of Multiplexers
C_{TX}	Cost of Transponders
C_{3R}	Cost of $3R$ regenerators

Table E.5: Header symbols and their description.

OPERATIONS	COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
	$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
Case 1																												
Mean	1	60.31	6963.16	59.20	30.32	2427.20	0.00	0.00	0.00	0.00	18.40	5.29	510.20	38.11	301.60	33.95	139.00	22.66	20.80	2.080	0.00	0.00	5.24	30.70	3680.00	26534.00	23640.00	15777.60
Min	1	60.39	6921.60	57.00	55.57	2433.00	0.00	0.00	0.00	0.00	20.00	5.78	508.00	38.08	300.00	33.81	137.00	22.33	18.00	1.800	0.00	0.00	5.19	31.00	4000.00	26360.00	23400.00	15456.00
Max	1	60.23	6999.20	62.00	52.21	2422.00	0.00	0.00	0.00	0.00	18.00	5.14	522.00	38.43	302.00	33.86	139.00	22.56	20.00	2.000	0.00	0.00	6.05	31.00	3600.00	26900.00	23700.00	15792.00
Mean	12	60.34	6947.72	59.70	23.82	24061.30	0.00	0.00	0.00	0.00	18.00	5.15	508.60	37.90	302.00	33.91	136.90	22.45	19.90	1.990	0.00	0.00	5.32	30.00	3600.00	26486.00	23700.00	15691.20
Min	12	60.25	6914.40	61.00	44.48	24249.00	0.00	0.00	0.00	0.00	18.00	5.15	506.00	38.05	302.00	33.92	132.00	21.85	20.00	2.000	0.00	0.00	5.27	33.00	3600.00	26580.00	23700.00	15264.00
Max	12	60.43	6974.80	61.00	3.46	22998.00	0.00	0.00	0.00	0.00	18.00	5.14	512.00	37.96	302.00	33.87	137.00	22.70	26.00	2.600	0.00	0.00	5.43	31.00	3600.00	26560.00	23700.00	15888.00
Mean	36	70.31	6950.44	61.00	37.26	29296.10	0.00	0.00	0.00	0.00	18.20	5.21	510.00	37.84	301.80	33.85	138.40	22.50	19.10	1.910	0.00	0.00	5.71	30.80	3640.00	26460.00	23670.00	15734.40
Min	36	72.10	6930.00	65.00	32.25	30081.00	0.00	0.00	0.00	0.00	18.00	5.16	512.00	37.85	302.00	33.98	137.00	22.37	21.00	2.100	0.00	0.00	6.05	31.00	3600.00	26400.00	23700.00	15600.00
Max	36	66.46	6974.40	64.00	19.09	27867.00	0.00	0.00	0.00	0.00	20.00	5.72	508.00	37.69	300.00	33.46	144.00	22.85	18.00	1.800	0.00	0.00	6.22	30.00	4000.00	26360.00	23400.00	15984.00
Mean	36*	62.76	6953.72	57.60	21.97	26240.50	0.00	0.00	0.00	0.00	18.80	5.41	510.60	38.27	300.60	33.86	137.80	22.46	20.30	2.030	0.00	0.00	4.94	30.60	3760.00	26614.00	23544.00	15619.20
Min	36*	61.35	6934.00	55.00	9.64	25869.00	0.00	0.00	0.00	0.00	18.00	5.19	500.00	38.13	302.00	34.18	134.00	22.50	16.00	1.600	0.00	0.00	4.70	27.00	3600.00	26440.00	23700.00	15600.00
Max	36*	61.01	6972.40	59.00	1.48	25845.00	0.00	0.00	0.00	0.00	18.00	5.16	516.00	37.92	302.00	33.99	141.00	22.92	18.00	1.800	0.00	0.00	6.24	30.00	3600.00	26440.00	23700.00	15984.00
Case 2																												
Mean	1	60.32	8052.64	58.10	32.50	2739.40	0.00	0.00	0.00	0.00	22.80	5.66	252.20	18.07	549.60	49.58	192.40	26.69	17.30	3.460	0.00	0.00	6.14	24.50	4560.00	14548.00	39924.00	21494.40
Min	1	60.25	8025.60	60.00	57.50	2748.00	0.00	0.00	0.00	0.00	24.00	5.98	256.00	18.09	548.00	49.49	191.00	26.44	22.00	4.400	0.00	0.00	5.41	23.00	4800.00	14520.00	39720.00	21216.00
Max	1	60.40	8073.20	58.00	57.39	2706.00	0.00	0.00	0.00	0.00	24.00	5.95	250.00	17.27	556.00	49.79	197.00	26.99	17.00	3.400	0.00	0.00	5.32	27.00	4800.00	13940.00	40200.00	21792.00
Mean	12	60.36	8029.64	56.70	32.60	24085.20	0.00	0.10	0.00	0.00	22.80	5.65	248.80	17.93	550.40	49.56	190.10	26.41	17.80	3.560	0.00	0.00	6.01	22.70	4560.00	14462.00	39972.00	21302.40
Min	12	60.45	7993.20	65.00	20.16	24257.00	0.00	0.00	0.00	0.00	22.00	5.45	248.00	17.87	550.00	49.53	188.00	26.08	17.00	3.400	0.00	0.00	5.22	22.00	4400.00	14440.00	40020.00	21072.00
Max	12	60.28	8052.40	68.00	58.11	25740.00	0.00	0.00	0.00	0.00	22.00	5.46	252.00	17.23	558.00	50.29	198.00	27.00	17.00	3.400	0.00	0.00	7.03	27.00	4400.00	13880.00	40500.00	21744.00
Mean	36	71.90	8026.24	57.90	34.88	29488.80	0.00	0.10	0.00	0.00	23.40	5.77	251.20	17.71	551.40	49.33	190.80	26.22	19.30	3.860	0.00	0.00	6.33	24.00	4680.00	14350.00	39978.00	21254.40
Min	36	74.54	7997.20	68.00	17.86	31066.00	0.00	0.00	0.00	0.00	22.00	5.46	248.00	17.36	558.00	50.21	191.00	26.13	23.00	4.600	0.00	0.00	5.73	27.00	4400.00	14000.00	40500.00	21072.00
Max	36	76.91	8040.80	57.00	13.78	30074.00	0.00	0.00	0.00	0.00	22.00	5.46	254.00	18.10	550.00	49.69	193.00	26.58	15.00	3.000	0.00	0.00	6.68	23.00	4400.00	14580.00	40020.00	21408.00
Mean	36*	63.26	8024.96	55.10	27.04	26120.40	0.00	0.20	0.00	0.00	22.40	5.58	250.40	17.93	551.20	49.92	190.60	26.57	17.10	3.420	0.00	0.00	6.04	23.90	4480.00	14392.00	40056.00	21321.60
Min	36*	61.28	7970.80	53.00	28.44	24841.00	0.00	0.00	0.00	0.00	22.00	5.52	252.00	17.41	558.00	50.81	191.00	26.26	18.00	3.600	0.00	0.00	6.32	24.00	4400.00	13880.00	40500.00	20928.00
Max	36*	60.90	8046.00	47.00	18.11	25588.00	0.00	0.00	0.00	0.00	22.00	5.47	242.00	18.25	546.00	49.44	186.00	26.85	15.00	3.000	0.00	0.00	5.89	23.00	4400.00	14680.00	39780.00	21600.00
Case 3																												
Mean	1	60.33	8044.72	51.20	24.22	3344.50	0.00	0.00	0.00	0.00	16.00	3.98	184.00	12.73	641.60	63.96	123.70	19.33	18.00	5.143	0.00	0.00	4.43	28.10	3200.00	10244.00	51456.00	15547.20
Min	1	60.42	8006.80	49.00	2.62	3348.00	0.00	0.00	0.00	0.00	16.00	4.00	186.00	12.61	644.00	64.45	119.00	18.94	16.00	4.571	0.00	0.00	4.95	24.00	3200.00	10100.00	51600.00	15168.00
Max	1	60.43	8076.40	50.00	15.07	3303.00	0.00	0.00	0.00	0.00	16.00	3.96	186.00	13.25	636.00	63.30	122.00	19.49	16.00	4.571	0.00	0.00	3.57	20.00	3200.00	10700.00	51120.00	15744.00
Mean	12	60.38	8023.88	50.60	21.59	33197.10	0.00	0.00	0.00	0.00	13.40	3.33	186.80	12.55	646.60	64.53	122.80	19.19	19.80	5.657	0.00	0.00	4.45	34.20	2680.00	10108.00	51990.00	15460.80
Min	12	60.25	8002.00	51.00	4.18	33844.00	0.00	0.00	0.00	0.00	12.00	2.99	190.00	12.84	648.00	65.08	120.00	18.85	19.00	5.429	0.00	0.00	4.16	35.00	2400.00	10300.00	52200.00	15120.00
Max	12	60.47	8040.80	49.00	32.82	34351.00	0.00	0.00	0.00	0.00	18.00	4.45	186.00	12.48	642.00	63.39	126.00	19.04	15.00	4.286	0.00	0.00	3.89	34.00	3600.00	10100.00	51300.00	15408.00
Mean	36	72.65	8019.68	51.30	28.16	41745.30	0.00	0.00	0.00	0.00	14.80	3.67	185.20	12.50	645.20	64.14	122.40	19.03	19.70	5.629	0.00	0.00	4.67	33.30	2960.00	10092.00	51780.00	15364.80
Min	36	65.83	8001.60	50.00	31.57	38230.00	0.00	0.00	0.00	0.00	12.00	3.00	180.00	12.45	648.00	65.24	122.00	19.32	20.00	5.714	0.00	0.00	4.59	36.00	2400.00	9960.00	52200.00	15456.00
Max	36	80.39	8045.20	51.00	4.10	44722.00	0.00	0.00	0.00	0.00	16.00	3.97	186.00	12.53	644.00	64.03	126.00	19.30	17.00	4.857	0.00	0.00	5.46	31.00	3200.00	10100.00	51600.00	15552.00
Mean	36*	63.98	8017.40	50.70	26.39	36252.00	0.00	0.00	0.00	0.00	14.40	3.59	185.40	12.62	645.60	64.66	121.50	19.13	20.00	5.714	0.00	0.00	4.40	31.10	2880.00	10118.00	51840.00	15336.00
Min	36*	65.71	7995.20	51.00	59.11	38648.00	0.00	0.00	0.00	0.00	16.00	4.00	176.00	12.61	644.00	64.54	118.00	18.85	19.00	5.429	0.00	0.00	4.57	33.00	3200.00	10080.00	51600.00	15072.00
Max	36*	60.92	8048.80	50.00	53.16	35443.00	0.00	0.00	0.00	0.00	24.00	5.96	180.00	12.57	636.00	62.62	122.00	18.85	18.00	5.143	0.00	0.00	4.35	27.00	4800.00	10120.00	50400.00	15168.00

Table E.6: Results of the best results of EON network cases 1, 2 and 3, for 60 seconds.

OPERATIONS	COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
	$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
Case 4																												
Mean	1	60.41	8668.56	65.80	34.22	1197.00	0.00	2.50	0.00	0.00	21.00	4.85	641.80	38.31	379.00	34.43	173.10	22.41	32.70	2.616	0.00	0.00	7.72	37.70	4200.00	33210.00	29850.00	19425.60
Min	1	60.54	8636.40	66.00	11.19	1185.00	0.00	3.00	0.00	0.00	20.00	4.63	646.00	38.51	380.00	34.74	169.00	22.12	32.00	2.560	0.00	0.00	8.38	43.00	4000.00	33260.00	30000.00	19104.00
Max	1	60.50	8697.60	65.00	20.67	1211.00	0.00	0.00	0.00	0.00	24.00	5.52	636.00	38.22	376.00	33.80	175.00	22.46	36.00	2.880	0.00	0.00	5.19	26.00	4800.00	33240.00	29400.00	19536.00
Mean	12	60.45	8650.08	65.30	28.43	12213.40	0.00	29.50	0.00	0.00	21.60	4.98	641.60	38.38	378.40	34.29	169.50	22.02	34.00	2.720	0.00	0.00	7.43	36.10	4320.00	33312.00	29760.00	19108.80
Min	12	60.36	8624.80	65.00	36.13	12539.00	0.00	24.00	0.00	0.00	20.00	4.60	636.00	38.23	380.00	34.51	165.00	21.86	31.00	2.480	0.00	0.00	5.92	28.00	4000.00	33240.00	30000.00	19008.00
Max	12	60.62	8666.00	68.00	13.40	12323.00	0.00	32.00	0.00	0.00	28.00	6.46	642.00	38.68	372.00	33.21	168.00	21.59	37.00	2.960	0.00	0.00	8.68	46.00	5600.00	33540.00	28800.00	18720.00
Mean	36	71.82	8646.44	64.90	30.95	15066.80	0.00	33.80	0.00	0.00	21.00	4.83	638.40	38.22	379.00	34.31	169.50	22.03	32.70	2.616	0.00	0.00	7.22	37.30	4200.00	33248.00	29850.00	19166.40
Min	36	77.97	8627.20	65.00	24.06	16214.00	0.00	43.00	0.00	0.00	20.00	4.62	640.00	38.22	380.00	34.62	168.00	22.10	31.00	2.480	0.00	0.00	7.54	37.00	4000.00	33120.00	30000.00	19152.00
Max	36	71.98	8664.00	63.00	15.29	15205.00	0.00	27.00	0.00	0.00	24.00	5.51	620.00	38.12	376.00	33.72	167.00	22.02	37.00	2.960	0.00	0.00	8.19	40.00	4800.00	33240.00	29400.00	19200.00
Mean	36*	61.79	8654.92	66.10	20.61	12832.90	0.00	30.70	0.00	0.00	22.20	5.13	638.80	38.33	377.80	34.28	172.50	22.26	33.00	2.640	0.00	0.00	7.05	36.80	4440.00	33172.00	29670.00	19267.20
Min	36*	61.09	8638.80	69.00	7.50	13098.00	0.00	25.00	0.00	0.00	26.00	6.02	636.00	38.29	374.00	33.69	174.00	22.00	29.00	2.320	0.00	0.00	8.30	43.00	5200.00	33080.00	29100.00	19008.00
Max	36*	67.17	8676.00	62.00	25.04	12932.00	0.00	33.00	0.00	0.00	18.00	4.15	638.00	38.24	382.00	34.92	175.00	22.68	28.00	2.240	0.00	0.00	6.30	28.00	3600.00	33180.00	30300.00	19680.00
Case 5																												
Mean	1	60.45	9815.16	79.30	28.71	933.60	0.00	933.60	43.10	0.00	24.80	5.05	325.80	21.13	664.80	49.92	192.00	23.90	33.00	5.280	0.00	0.00	9.71	35.70	4960.00	20738.00	48996.00	23457.60
Min	1	60.57	9791.60	80.00	3.95	920.00	0.00	920.00	50.00	0.00	26.00	5.31	328.00	21.06	666.00	50.00	190.00	23.63	36.00	5.760	0.00	0.00	9.86	42.00	5200.00	20620.00	48960.00	23136.00
Max	1	60.34	9834.40	80.00	40.79	936.00	0.00	936.00	45.00	0.00	26.00	5.29	310.00	20.87	666.00	49.78	194.00	24.06	29.00	4.640	0.00	0.00	10.00	37.00	5200.00	20520.00	48960.00	23664.00
Mean	12	60.50	9774.24	80.00	30.76	9709.10	0.00	9709.00	401.00	0.00	23.80	4.85	326.20	21.15	665.80	50.07	190.30	23.51	33.90	5.424	0.00	0.00	9.44	34.90	4760.00	20758.00	49146.00	23078.40
Min	12	60.40	9718.40	80.00	14.55	9610.00	0.00	9610.00	389.00	0.00	22.00	4.49	326.00	20.93	670.00	50.54	184.00	23.15	33.00	5.280	0.00	0.00	10.22	39.00	4400.00	20520.00	49560.00	22704.00
Max	12	60.36	9795.20	80.00	2.79	9897.00	0.00	9897.00	393.00	0.00	24.00	4.89	324.00	20.81	668.00	50.20	195.00	23.92	34.00	5.440	0.00	0.00	7.73	30.00	4800.00	20420.00	49260.00	23472.00
Mean	36	73.63	9773.44	79.60	30.90	12003.00	0.00	12003.00	515.30	0.00	23.80	4.84	326.20	21.37	662.60	49.79	187.00	23.40	34.80	5.568	0.00	0.00	9.24	34.70	4760.00	21014.00	48954.00	23006.40
Min	36	72.34	9740.40	80.00	35.48	11970.00	0.00	11970.00	513.00	0.00	22.00	4.47	320.00	21.82	662.00	49.90	183.00	22.84	33.00	5.280	0.00	0.00	9.70	33.00	4400.00	21460.00	49080.00	22464.00
Max	36	67.81	9794.00	79.00	51.51	11274.00	0.00	11274.00	495.00	0.00	22.00	4.47	332.00	21.29	662.00	49.90	191.00	23.91	31.00	4.960	0.00	0.00	8.27	35.00	4400.00	20940.00	49080.00	23520.00
Mean	36*	63.34	9782.52	79.70	29.19	10057.50	0.00	10057.50	419.50	0.00	23.80	4.87	330.80	21.52	662.60	50.04	189.20	23.57	34.40	5.504	0.00	0.00	9.34	34.60	4760.00	21052.00	48954.00	23059.20
Min	36*	69.05	9718.40	80.00	28.38	10695.00	0.00	10695.00	429.00	0.00	22.00	4.53	326.00	21.11	670.00	51.00	184.00	23.36	33.00	5.280	0.00	0.00	10.22	39.00	4400.00	20520.00	49560.00	22704.00
Max	36*	61.40	9805.60	80.00	23.45	9913.00	0.00	9913.00	423.00	0.00	24.00	4.90	336.00	21.27	668.00	50.24	196.00	23.59	31.00	4.960	0.00	0.00	10.41	34.00	4800.00	20860.00	49260.00	23136.00
Case 6																												
Mean	1	60.44	10604.32	78.60	31.84	1033.00	0.00	1033.00	0.10	0.00	41.60	7.85	249.20	13.58	766.00	56.79	196.30	21.79	30.00	6.849	0.00	0.00	9.26	36.40	8320.00	14400.00	60216.00	23107.20
Min	1	60.33	10577.20	78.00	30.98	1030.00	0.00	1030.00	0.00	0.00	38.00	7.19	252.00	13.50	772.00	57.58	193.00	21.74	32.00	7.306	0.00	0.00	8.76	45.00	7600.00	14280.00	60900.00	22992.00
Max	1	60.57	10632.40	80.00	41.34	1056.00	0.00	1056.00	0.00	0.00	42.00	7.90	252.00	13.58	768.00	56.71	195.00	21.81	29.00	6.621	0.00	0.00	8.30	29.00	8400.00	14440.00	60300.00	23184.00
Mean	12	60.53	10559.48	79.10	30.43	10756.80	0.00	10756.80	1.30	0.00	41.20	7.77	249.60	13.45	767.60	56.88	192.40	21.43	30.80	7.032	0.00	0.00	9.21	36.60	8240.00	14274.00	60348.00	22732.80
Min	12	60.36	10542.80	79.00	37.60	10463.00	0.00	10463.00	1.00	0.00	52.00	9.77	248.00	14.14	746.00	54.54	189.00	20.55	34.00	7.763	0.00	0.00	10.41	31.00	10400.00	15060.00	58080.00	21888.00
Max	12	60.36	10580.40	80.00	1.47	11139.00	0.00	11139.00	0.00	0.00	36.00	6.78	246.00	13.17	774.00	57.67	196.00	22.07	25.00	5.708	0.00	0.00	9.19	35.00	7200.00	13980.00	61200.00	23424.00
Mean	36	72.93	10549.92	78.40	28.05	13477.80	0.00	13477.80	2.40	0.00	42.00	7.90	247.60	13.39	766.40	56.59	192.00	21.29	29.50	6.735	0.00	0.00	9.32	37.70	8400.00	14244.00	60204.00	22651.20
Min	36	75.83	10493.20	78.00	8.21	13665.00	0.00	13665.00	2.00	0.00	44.00	8.27	254.00	13.92	758.00	55.92	185.00	20.48	26.00	5.936	0.00	0.00	10.30	34.00	8800.00	14820.00	59520.00	21792.00
Max	36	77.27	10605.60	79.00	49.62	14395.00	0.00	14395.00	3.00	0.00	46.00	8.65	250.00	13.18	764.00	56.12	199.00	21.75	29.00	6.621	0.00	0.00	8.81	32.00	9200.00	14020.00	59700.00	23136.00
Mean	36*	63.50	10563.92	79.10	28.14	11341.50	0.00	11341.50	1.60	0.00	42.80	8.10	246.80	13.44	768.00	57.01	192.90	21.44	31.70	7.237	0.00	0.00	9.51	36.00	8560.00	14200.00	60228.00	22651.20
Min	36*	71.17	10540.00	79.00	36.01	12474.00	0.00	12474.00	0.00	0.00	54.00	10.25	250.00	13.76	756.00	55.50	189.00	20.49	31.00	7.078	0.00	0.00	9.76	36.00	10800.00	14500.00	58500.00	21600.00
Max	36*	60.94	10582.40	79.00	55.36	11223.00	0.00	11223.00	3.00	0.00	38.00	7.18	246.00	13.36	772.00	57.55	195.00	21.91	27.00	6.164	0.00	0.00	8.76	43.00	7600.00	14140.00	60900.00	23184.00

Table E.7: Results of the best results of EON network cases 4, 5 and 6, for 60 seconds.

OPERATIONS	COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
	$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
Case 7																												
Mean	1	60.60	11918.68	80.00	22.20	366.30	0.00	366.30	99.90	0.00	21.00	3.52	771.40	38.47	444.40	30.30	258.70	27.71	61.20	3.916	0.00	0.00	6.86	36.30	4200.00	45854.00	36114.00	33028.80
Min	1	60.39	11836.00	80.00	44.23	365.00	0.00	365.00	96.00	0.00	18.00	3.04	774.00	38.66	444.00	30.72	250.00	27.58	58.00	3.711	0.00	0.00	8.65	43.00	3600.00	45760.00	36360.00	32640.00
Max	1	60.37	11960.40	80.00	57.74	377.00	0.00	377.00	115.00	0.00	24.00	4.01	784.00	39.63	428.00	29.15	255.00	27.21	70.00	4.479	0.00	0.00	8.19	28.00	4800.00	47400.00	34860.00	32544.00
Mean	12	60.73	11860.16	80.00	30.93	3850.60	0.00	3850.60	1049.10	0.00	19.40	3.25	767.00	37.71	454.20	30.82	257.40	27.46	56.90	3.640	0.00	0.00	6.51	30.30	3880.00	45068.00	36846.00	32817.60
Min	12	60.50	11753.20	80.00	53.01	3873.00	0.00	3873.00	1067.00	0.00	24.00	4.01	758.00	36.74	458.00	30.64	258.00	26.84	54.00	3.455	0.00	0.00	5.76	41.00	4800.00	43960.00	36660.00	32112.00
Max	12	60.62	11918.00	80.00	9.36	3827.00	0.00	3827.00	1033.00	0.00	24.00	4.00	750.00	37.01	458.00	30.58	265.00	27.83	55.00	3.519	0.00	0.00	4.03	20.00	4800.00	44360.00	36660.00	33360.00
Mean	36	72.05	11861.88	80.00	33.49	4603.10	0.00	4603.10	1233.30	0.00	19.00	3.17	767.60	37.60	453.40	30.67	255.60	27.38	56.70	3.628	0.00	0.00	6.89	38.30	3800.00	45132.00	36816.00	32860.80
Min	36	67.11	11815.60	80.00	42.14	4213.00	0.00	4213.00	1116.00	0.00	18.00	3.01	764.00	37.02	464.00	31.41	257.00	27.38	55.00	3.519	0.00	0.00	8.27	44.00	3600.00	44260.00	37560.00	32736.00
Max	36	71.48	11910.80	80.00	26.32	4662.00	0.00	4662.00	1286.00	0.00	22.00	3.67	768.00	37.63	452.00	30.46	257.00	27.70	62.00	3.967	0.00	0.00	7.68	47.00	4400.00	45060.00	36480.00	33168.00
Mean	36*	63.61	11854.32	80.00	39.33	4003.00	0.00	4003.00	1090.50	0.00	20.80	3.51	762.60	38.16	450.60	30.79	255.60	27.55	57.30	3.666	0.00	0.00	6.91	31.00	4160.00	45230.00	36504.00	32659.20
Min	36*	76.74	11753.20	80.00	52.93	4321.00	0.00	4321.00	1162.00	0.00	24.00	4.08	758.00	37.40	458.00	31.19	258.00	27.32	54.00	3.455	0.00	0.00	5.76	41.00	4800.00	43960.00	36660.00	32112.00
Max	36*	61.76	11918.00	80.00	45.76	3857.00	0.00	3857.00	1059.00	0.00	24.00	4.03	750.00	37.22	458.00	30.76	265.00	27.99	55.00	3.519	0.00	0.00	4.03	20.00	4800.00	44360.00	36660.00	33360.00
Case 8																												
Mean	1	60.53	12185.20	77.90	36.49	547.40	0.00	320.20	0.00	0.00	37.00	6.07	392.00	18.68	864.60	51.51	267.80	23.73	38.20	4.885	0.00	0.00	9.64	42.80	7400.00	22766.00	62766.00	28920.00
Min	1	60.68	12128.80	79.00	26.24	546.00	0.00	310.00	0.00	0.00	42.00	6.93	380.00	18.53	860.00	51.15	267.00	23.39	35.00	4.476	0.00	0.00	9.92	45.00	8400.00	22480.00	62040.00	28368.00
Max	1	60.37	12231.60	75.00	48.45	550.00	0.00	327.00	0.00	0.00	32.00	5.23	392.00	18.61	870.00	51.95	268.00	24.21	35.00	4.476	0.00	0.00	9.16	36.00	6400.00	22760.00	63540.00	29616.00
Mean	12	60.67	12138.84	78.80	32.47	5781.40	0.00	3377.60	0.20	0.00	36.20	5.94	391.20	18.57	865.80	51.61	262.80	23.46	41.30	5.281	0.00	0.00	9.82	45.00	7240.00	22640.00	62910.00	28598.40
Min	12	60.89	12094.40	78.00	43.37	5772.00	0.00	3383.00	0.00	0.00	36.00	5.91	390.00	18.74	866.00	51.70	254.00	22.99	39.00	4.987	0.00	0.00	8.59	41.00	7200.00	22820.00	62940.00	27984.00
Max	12	60.47	12167.60	80.00	29.33	5920.00	0.00	3477.00	0.00	0.00	38.00	6.25	394.00	18.52	864.00	51.48	271.00	23.75	36.00	4.604	0.00	0.00	12.62	50.00	7600.00	22540.00	62640.00	28896.00
Mean	36	72.74	12147.36	78.20	22.31	7107.50	0.00	4132.30	0.00	0.00	37.40	6.12	387.80	18.54	864.00	51.28	264.00	23.43	38.40	4.910	0.00	0.00	10.19	50.20	7480.00	22658.00	62694.00	28641.60
Min	36	74.76	12122.00	77.00	45.91	7239.00	0.00	4219.00	0.00	0.00	34.00	5.58	394.00	18.75	868.00	51.86	259.00	23.22	43.00	5.499	0.00	0.00	11.32	52.00	6800.00	22860.00	63240.00	28320.00
Max	36	73.63	12174.40	79.00	6.43	7054.00	0.00	4076.00	0.00	0.00	38.00	6.21	388.00	18.43	864.00	51.17	264.00	23.64	40.00	5.115	0.00	0.00	9.24	42.00	7600.00	22560.00	62640.00	28944.00
Mean	36*	63.37	12154.84	78.30	25.81	6073.10	0.00	3555.30	0.20	0.00	37.20	6.12	387.80	18.67	864.20	51.60	263.50	23.61	39.20	5.013	0.00	0.00	9.91	45.70	7440.00	22690.00	62724.00	28694.40
Min	36*	75.89	12127.20	76.00	11.70	7432.00	0.00	4415.00	0.00	0.00	40.00	6.60	390.00	18.69	862.00	51.41	263.00	23.31	39.00	4.987	0.00	0.00	10.41	44.00	8000.00	22660.00	62340.00	28272.00
Max	36*	61.35	12186.40	78.00	34.29	5984.00	0.00	3463.00	0.00	0.00	38.00	6.24	392.00	18.81	864.00	51.40	263.00	23.55	45.00	5.754	0.00	0.00	10.19	41.00	7600.00	22920.00	62640.00	28704.00
Case 9																												
Mean	1	60.58	14631.68	80.00	31.91	327.30	0.00	327.30	5.40	0.00	47.00	6.42	314.00	12.53	965.00	52.06	357.80	28.99	47.80	8.723	0.00	0.00	8.56	35.60	9400.00	18334.00	76170.00	42412.80
Min	1	60.79	14593.60	80.00	6.24	325.00	0.00	325.00	5.00	0.00	44.00	6.03	304.00	12.38	970.00	52.58	351.00	29.01	56.00	10.219	0.00	0.00	6.86	31.00	8800.00	18060.00	76740.00	42336.00
Max	1	60.50	14706.00	80.00	7.60	326.00	0.00	326.00	6.00	0.00	46.00	6.26	328.00	13.37	952.00	51.33	361.00	29.05	50.00	9.124	0.00	0.00	8.78	39.00	9200.00	19660.00	75480.00	42720.00
Mean	12	60.80	14539.84	80.00	18.63	3504.10	0.00	3504.10	68.00	0.00	49.20	6.72	313.00	12.39	964.60	51.86	350.30	28.31	48.80	8.905	0.00	0.00	8.31	35.10	9840.00	18148.00	75948.00	41462.40
Min	12	61.00	14466.40	80.00	18.85	3526.00	0.00	3526.00	70.00	0.00	48.00	6.56	318.00	12.53	964.00	51.93	343.00	27.80	53.00	9.672	0.00	0.00	7.65	29.00	9600.00	18340.00	76020.00	40704.00
Max	12	60.65	14583.60	80.00	24.91	3543.00	0.00	3543.00	82.00	0.00	56.00	7.66	314.00	12.37	958.00	51.26	351.00	28.47	50.00	9.124	0.00	0.00	8.78	45.00	11200.00	18080.00	74940.00	41616.00
Mean	36	72.47	14552.60	80.00	26.84	4270.00	0.00	4270.00	78.40	0.00	48.20	6.56	315.80	12.36	965.40	51.79	352.60	28.34	50.20	9.161	0.00	0.00	8.21	35.30	9640.00	18160.00	76086.00	41640.00
Min	36	74.80	14529.20	80.00	29.08	4355.00	0.00	4355.00	89.00	0.00	52.00	7.05	318.00	12.27	962.00	51.17	356.00	27.93	51.00	9.307	0.00	0.00	7.32	30.00	10400.00	18120.00	75540.00	41232.00
Max	36	75.04	14592.00	80.00	1.69	4392.00	0.00	4392.00	80.00	0.00	48.00	6.52	308.00	12.19	966.00	51.75	347.00	28.71	53.00	9.672	0.00	0.00	8.84	44.00	9600.00	17940.00	76140.00	42240.00
Mean	36*	63.14	14555.08	80.00	30.64	3601.20	0.00	3601.20	67.50	0.00	47.80	6.57	313.40	12.50	965.80	52.32	350.40	28.61	48.00	8.759	0.00	0.00	8.09	37.30	9560.00	18200.00	76146.00	41644.80
Min	36*	66.30	14526.80	80.00	41.31	3727.00	0.00	3727.00	68.00	0.00	48.00	6.61	318.00	12.36	966.00	52.41	346.00	28.61	48.00	8.759	0.00	0.00	7.78	28.00	9600.00	17960.00	76140.00	41568.00
Max	36*	61.67	14603.60	80.00	48.52	3611.00	0.00	3611.00	75.00	0.00	48.00	6.57	322.00	12.96	958.00	51.81	355.00	28.66	45.00	8.212	0.00	0.00	7.68	30.00	9600.00	18920.00	75660.00	41856.00

Table E.8: Results of the best results of EON network cases 7, 8 and 9, for 60 seconds.

E.3 GBN best results for 60 seconds.

Symbol	Name
$\#T$	Number of Threads
t_E	Time of Execution
C	Best Cost Solution found
CA	Highest Channel Assigned
t_{sol}	Found Solution Time
$\#i$	Number of Iterations
$\#IS$	Number of Invalid Solutions
$\#G_U$	Number of Greedy Solutions Unfeasible
$\#LS_U$	Number of Local Search Solutions Unfeasible
UD	Unfeasible Degree
$\#IM$	Number of Invert Multiplex used
C_{IM}	Cost % of Invert Multiplex
$\#MX$	Number of Muxponders placed
C_{MX}	Cost % of Muxponders
$\#TX$	Number of Transponders placed
C_{TX}	Cost % of Transponders
$\#3R$	Number of $3R$ regenerators placed
C_{3R}	Cost % of $3R$ regenerators
$\#10$	Number of Multi-Hop Grooming of $10Gb/s$
$\%10$	Traffic % of Multi-Hop Grooming of $10Gb/s$
$\#40$	Number of Multi-hop Grooming of $40Gb/s$
$\%40$	Traffic % of Multi-hop Grooming of $40Gb/s$
$\bar{m}F$	Average Fragmentation at Channel Assigned
MF	Max Fragmentation at Channel Assigned
C_{IM}	Cost of Invert Multiplexers
C_{MX}	Cost of Multiplexers
C_{TX}	Cost of Transponders
C_{3R}	Cost of $3R$ regenerators

Table E.9: Header symbols and their description.

OPERATIONS	COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
	$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
Case 1																												
Mean	1	60.29	4736.00	58.00	27.49	9408.60	0.00	0.00	0.00	0.00	0.00	0.00	464.00	49.32	280.00	50.68	0.00	0.00	11.70	1.300	0.00	0.00	12.42	32.10	0.00	23360.00	24000.00	0.00
Min	1	60.36	4736.00	55.00	2.56	9415.00	0.00	0.00	0.00	0.00	0.00	0.00	464.00	49.32	280.00	50.68	0.00	0.00	13.00	1.444	0.00	0.00	10.73	25.00	0.00	23360.00	24000.00	0.00
Max	1	60.36	4736.00	62.00	42.65	9427.00	0.00	0.00	0.00	0.00	0.00	0.00	464.00	49.32	280.00	50.68	0.00	0.00	11.00	1.222	0.00	0.00	14.58	37.00	0.00	23360.00	24000.00	0.00
Mean	12	60.32	4731.40	58.10	38.55	91970.30	0.00	0.00	0.00	0.00	0.00	0.00	465.00	49.26	280.00	50.71	0.00	0.00	10.40	1.156	0.00	0.00	12.35	30.90	0.00	23314.00	24000.00	0.00
Min	12	60.23	4736.00	56.00	22.15	89213.00	0.00	0.00	0.00	0.00	0.00	0.00	464.00	49.32	280.00	50.68	0.00	0.00	12.00	1.333	0.00	0.00	10.73	24.00	0.00	23360.00	24000.00	0.00
Max	12	60.22	4736.00	56.00	57.58	94761.00	0.00	0.00	0.00	0.00	0.00	0.00	464.00	49.32	280.00	50.68	0.00	0.00	9.00	1.000	0.00	0.00	11.27	31.00	0.00	23360.00	24000.00	0.00
Mean	36	70.37	4730.00	59.00	27.99	112217.20	0.00	0.00	0.00	0.00	0.00	0.00	466.00	49.21	280.00	50.68	0.00	0.00	9.80	1.089	0.00	0.00	12.47	30.40	0.00	23300.00	24000.00	0.00
Min	36	67.72	4730.00	57.00	3.29	110460.00	0.00	0.00	0.00	0.00	0.00	0.00	466.00	49.20	280.00	50.68	0.00	0.00	11.00	1.222	0.00	0.00	10.85	31.00	0.00	23300.00	24000.00	0.00
Max	36	66.02	4730.00	61.00	29.75	105648.00	0.00	0.00	0.00	0.00	0.00	0.00	466.00	49.20	280.00	50.68	0.00	0.00	8.00	0.889	0.00	0.00	12.65	28.00	0.00	23300.00	24000.00	0.00
Mean	36*	70.37	4730.00	59.00	27.99	112217.20	0.00	0.00	0.00	0.00	0.00	0.00	466.00	49.21	280.00	50.68	0.00	0.00	9.80	1.089	0.00	0.00	12.47	30.40	0.00	23300.00	24000.00	0.00
Min	36*	67.72	4730.00	57.00	3.29	110460.00	0.00	0.00	0.00	0.00	0.00	0.00	466.00	49.20	280.00	50.68	0.00	0.00	11.00	1.222	0.00	0.00	10.85	31.00	0.00	23300.00	24000.00	0.00
Max	36*	66.02	4730.00	61.00	29.75	105648.00	0.00	0.00	0.00	0.00	0.00	0.00	466.00	49.20	280.00	50.68	0.00	0.00	8.00	0.889	0.00	0.00	12.65	28.00	0.00	23300.00	24000.00	0.00
Case 2																												
Mean	1	60.28	5177.80	73.50	26.03	10474.30	0.00	370.80	27.20	0.00	0.00	0.00	211.00	22.94	530.00	77.06	0.00	0.00	8.70	1.933	0.00	0.00	15.43	34.60	0.00	11878.00	39900.00	0.00
Min	1	60.36	5176.00	73.00	23.17	10472.00	0.00	349.00	22.00	0.00	0.00	0.00	202.00	22.91	530.00	77.09	0.00	0.00	8.00	1.778	0.00	0.00	16.35	37.00	0.00	11860.00	39900.00	0.00
Max	1	60.22	5178.00	76.00	11.43	10458.00	0.00	384.00	29.00	0.00	0.00	0.00	212.00	22.94	530.00	77.06	0.00	0.00	8.00	1.778	0.00	0.00	16.00	33.00	0.00	11880.00	39900.00	0.00
Mean	12	60.33	5177.60	72.60	22.22	89527.80	0.00	3116.90	216.50	0.00	0.00	0.00	210.00	22.94	530.00	77.06	0.00	0.00	8.30	1.844	0.00	0.00	16.55	37.60	0.00	11876.00	39900.00	0.00
Min	12	60.31	5176.00	73.00	28.39	87356.00	0.00	2994.00	167.00	0.00	0.00	0.00	202.00	22.90	530.00	77.06	0.00	0.00	8.00	1.778	0.00	0.00	15.96	33.00	0.00	11860.00	39900.00	0.00
Max	12	60.37	5178.00	72.00	47.35	93468.00	0.00	3292.00	236.00	0.00	0.00	0.00	212.00	22.94	530.00	77.06	0.00	0.00	8.00	1.778	0.00	0.00	18.00	35.00	0.00	11880.00	39900.00	0.00
Mean	36	70.09	5177.80	72.40	18.13	107100.10	0.00	3717.20	266.00	0.00	0.00	0.00	211.00	22.93	530.00	77.04	0.00	0.00	8.40	1.867	0.00	0.00	15.43	34.20	0.00	11878.00	39900.00	0.00
Min	36	66.80	5176.00	75.00	19.11	102194.00	0.00	3574.00	261.00	0.00	0.00	0.00	202.00	22.90	530.00	77.06	0.00	0.00	8.00	1.778	0.00	0.00	17.19	40.00	0.00	11860.00	39900.00	0.00
Max	36	72.31	5178.00	73.00	7.58	109030.00	0.00	3722.00	259.00	0.00	0.00	0.00	212.00	22.94	530.00	77.06	0.00	0.00	10.00	2.222	0.00	0.00	14.27	28.00	0.00	11880.00	39900.00	0.00
Mean	36*	72.30	5178.00	72.10	29.08	102912.40	0.00	3559.70	251.60	0.00	0.00	0.00	212.00	22.94	530.00	77.06	0.00	0.00	8.30	1.844	0.00	0.00	15.66	34.60	0.00	11880.00	39900.00	0.00
Min	36*	73.21	5178.00	72.00	3.43	96258.00	0.00	3250.00	214.00	0.00	0.00	0.00	212.00	22.94	530.00	77.06	0.00	0.00	7.00	1.556	0.00	0.00	13.00	26.00	0.00	11880.00	39900.00	0.00
Max	36*	73.77	5178.00	73.00	35.55	109802.00	0.00	3732.00	257.00	0.00	0.00	0.00	212.00	22.94	530.00	77.06	0.00	0.00	8.00	1.778	0.00	0.00	17.62	39.00	0.00	11880.00	39900.00	0.00
Case 3																												
Mean	1	60.28	5571.80	60.60	34.40	9310.40	0.00	0.00	0.00	0.00	0.00	0.00	149.40	14.93	580.00	85.07	0.00	0.00	12.30	4.100	0.00	0.00	13.60	34.00	0.00	8318.00	47400.00	0.00
Min	1	60.37	5566.00	62.00	39.78	9313.00	0.00	0.00	0.00	0.00	0.00	0.00	146.00	14.84	580.00	85.16	0.00	0.00	13.00	4.333	0.00	0.00	13.65	35.00	0.00	8260.00	47400.00	0.00
Max	1	60.22	5576.00	58.00	1.67	9345.00	0.00	0.00	0.00	0.00	0.00	0.00	148.00	14.99	580.00	85.01	0.00	0.00	12.00	4.000	0.00	0.00	12.92	40.00	0.00	8360.00	47400.00	0.00
Mean	12	60.29	5568.00	59.40	36.74	89838.40	0.00	0.00	0.00	0.00	0.00	0.00	148.00	14.86	580.00	85.07	0.00	0.00	11.80	3.933	0.00	0.00	13.21	36.30	0.00	8280.00	47400.00	0.00
Min	12	60.22	5566.00	56.00	46.91	87871.00	0.00	0.00	0.00	0.00	0.00	0.00	146.00	14.84	580.00	85.16	0.00	0.00	12.00	4.000	0.00	0.00	11.96	35.00	0.00	8260.00	47400.00	0.00
Max	12	60.22	5570.00	64.00	51.20	87385.00	0.00	0.00	0.00	0.00	0.00	0.00	150.00	14.89	580.00	85.04	0.00	0.00	11.00	3.667	0.00	0.00	13.88	37.00	0.00	8300.00	47400.00	0.00
Mean	36	72.44	5568.80	58.50	35.39	114973.40	0.00	0.00	0.00	0.00	0.00	0.00	148.80	14.86	580.00	85.00	0.00	0.00	12.50	4.167	0.00	0.00	12.53	32.20	0.00	8288.00	47400.00	0.00
Min	36	67.13	5566.00	58.00	37.10	107557.00	0.00	0.00	0.00	0.00	0.00	0.00	146.00	14.81	580.00	85.01	0.00	0.00	13.00	4.333	0.00	0.00	13.46	39.00	0.00	8260.00	47400.00	0.00
Max	36	66.16	5570.00	60.00	56.38	106181.00	0.00	0.00	0.00	0.00	0.00	0.00	150.00	14.87	580.00	84.95	0.00	0.00	14.00	4.667	0.00	0.00	12.58	33.00	0.00	8300.00	47400.00	0.00
Mean	36*	67.28	5568.80	58.60	34.54	104029.90	0.00	0.00	0.00	0.00	0.00	0.00	148.80	14.88	580.00	85.12	0.00	0.00	12.80	4.267	0.00	0.00	12.35	31.90	0.00	8288.00	47400.00	0.00
Min	36*	74.30	5566.00	57.00	22.61	114750.00	0.00	0.00	0.00	0.00	0.00	0.00	146.00	14.84	580.00	85.16	0.00	0.00	16.00	5.333	0.00	0.00	12.00	35.00	0.00	8260.00	47400.00	0.00
Max	36*	60.90	5570.00	60.00	52.81	97462.00	0.00	0.00	0.00	0.00	0.00	0.00	150.00	14.90	580.00	85.10	0.00	0.00	13.00	4.333	0.00	0.00	11.58	33.00	0.00	8300.00	47400.00	0.00

Table E.10: Results of the best results of GBN network cases 1, 2 and 3, for 60 seconds.

OPERATIONS	COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
	$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
Case 4																												
Mean	1	60.45	5693.80	78.80	30.28	4089.20	0.00	1837.20	260.60	0.00	0.00	0.00	547.40	49.42	336.00	50.58	0.00	0.00	20.80	1.926	0.00	0.00	12.62	33.90	0.00	28138.00	28800.00	0.00
Min	1	60.51	5688.00	80.00	23.90	4061.00	0.00	1847.00	274.00	0.00	0.00	0.00	552.00	49.37	336.00	50.63	0.00	0.00	17.00	1.574	0.00	0.00	12.27	27.00	0.00	28080.00	28800.00	0.00
Max	1	60.51	5696.00	79.00	23.24	4086.00	0.00	1824.00	264.00	0.00	0.00	0.00	544.00	49.44	336.00	50.56	0.00	0.00	21.00	1.944	0.00	0.00	12.73	32.00	0.00	28160.00	28800.00	0.00
Mean	12	60.46	5688.40	78.20	30.94	39672.70	0.00	17688.60	2539.80	0.00	0.00	0.00	546.00	49.32	336.00	50.58	0.00	0.00	19.80	1.833	0.00	0.00	12.53	32.30	0.00	28084.00	28800.00	0.00
Min	12	60.36	5684.00	78.00	6.96	39844.00	0.00	17803.00	2588.00	0.00	0.00	0.00	548.00	49.23	336.00	50.56	0.00	0.00	20.00	1.852	0.00	0.00	12.46	36.00	0.00	28040.00	28800.00	0.00
Max	12	60.39	5690.00	80.00	26.88	41248.00	0.00	18413.00	2663.00	0.00	0.00	0.00	546.00	49.32	336.00	50.54	0.00	0.00	17.00	1.574	0.00	0.00	10.73	34.00	0.00	28100.00	28800.00	0.00
Mean	36	71.40	5688.60	78.30	32.47	46201.40	0.00	20616.50	2957.40	0.00	0.00	0.00	545.40	49.29	336.00	50.55	0.00	0.00	20.00	1.852	0.00	0.00	12.10	30.30	0.00	28086.00	28800.00	0.00
Min	36	70.14	5686.00	78.00	33.99	45989.00	0.00	20582.00	3001.00	0.00	0.00	0.00	542.00	49.26	336.00	50.56	0.00	0.00	20.00	1.852	0.00	0.00	12.96	41.00	0.00	28060.00	28800.00	0.00
Max	36	69.20	5690.00	80.00	32.12	45410.00	0.00	20171.00	2932.00	0.00	0.00	0.00	546.00	49.28	336.00	50.51	0.00	0.00	19.00	1.759	0.00	0.00	11.50	35.00	0.00	28100.00	28800.00	0.00
Mean	36*	63.46	5688.20	77.90	29.53	42240.60	0.00	18849.80	2689.00	0.00	0.00	0.00	546.60	49.37	336.00	50.63	0.00	0.00	21.40	1.981	0.00	0.00	12.80	30.40	0.00	28082.00	28800.00	0.00
Min	36*	61.01	5684.00	77.00	21.84	41924.00	0.00	18637.00	2596.00	0.00	0.00	0.00	548.00	49.33	336.00	50.67	0.00	0.00	21.00	1.944	0.00	0.00	12.85	28.00	0.00	28040.00	28800.00	0.00
Max	36*	61.14	5692.00	76.00	7.71	42403.00	0.00	18785.00	2734.00	0.00	0.00	0.00	540.00	49.40	336.00	50.60	0.00	0.00	22.00	2.037	0.00	0.00	15.58	35.00	0.00	28120.00	28800.00	0.00
Case 5																												
Mean	1	60.45	6234.80	78.80	24.82	3431.50	0.00	2945.60	201.50	0.00	0.00	0.00	258.00	23.21	636.00	76.79	0.00	0.00	15.10	2.796	0.00	0.00	11.78	34.80	0.00	14468.00	47880.00	0.00
Min	1	60.54	6228.00	79.00	13.93	3419.00	0.00	2945.00	204.00	0.00	0.00	0.00	272.00	23.12	636.00	76.88	0.00	0.00	17.00	3.148	0.00	0.00	12.31	35.00	0.00	14400.00	47880.00	0.00
Max	1	60.54	6240.00	77.00	18.17	3410.00	0.00	2953.00	210.00	0.00	0.00	0.00	252.00	23.27	636.00	76.73	0.00	0.00	15.00	2.778	0.00	0.00	12.35	35.00	0.00	14520.00	47880.00	0.00
Mean	12	61.50	6229.40	78.90	25.84	32916.70	0.00	28242.80	1972.00	0.00	0.00	0.00	258.20	23.11	636.00	76.78	0.00	0.00	14.80	2.741	0.00	0.00	12.18	37.20	0.00	14414.00	47880.00	0.00
Min	12	60.37	6226.00	79.00	22.60	33109.00	0.00	28444.00	2033.00	0.00	0.00	0.00	262.00	23.10	636.00	76.90	0.00	0.00	14.00	2.593	0.00	0.00	11.92	33.00	0.00	14380.00	47880.00	0.00
Max	12	60.56	6232.00	79.00	19.34	33382.00	0.00	28627.00	1986.00	0.00	0.00	0.00	260.00	23.15	636.00	76.76	0.00	0.00	17.00	3.148	0.00	0.00	12.88	40.00	0.00	14440.00	47880.00	0.00
Mean	36	73.55	6229.80	78.60	33.48	42096.10	16.50	36166.40	2540.30	0.00	0.00	0.00	252.20	23.10	636.00	76.71	0.00	0.00	14.70	2.722	0.00	0.00	11.56	30.70	0.00	14418.00	47880.00	0.00
Min	36	72.38	6228.00	78.00	16.79	42115.00	0.00	36337.00	2526.00	0.00	0.00	0.00	256.00	23.06	636.00	76.68	0.00	0.00	17.00	3.148	0.00	0.00	10.65	29.00	0.00	14400.00	47880.00	0.00
Max	36	82.07	6232.00	80.00	25.02	45213.00	0.00	38798.00	2684.00	0.00	0.00	0.00	244.00	23.14	636.00	76.73	0.00	0.00	13.00	2.407	0.00	0.00	12.81	29.00	0.00	14440.00	47880.00	0.00
Mean	36*	62.61	6230.00	78.80	25.18	35210.80	0.00	30272.30	2128.50	0.00	0.00	0.00	254.80	23.15	636.00	76.85	0.00	0.00	15.40	2.852	0.00	0.00	12.09	35.60	0.00	14420.00	47880.00	0.00
Min	36*	61.25	6228.00	78.00	17.46	35114.00	0.00	30279.00	2106.00	0.00	0.00	0.00	256.00	23.12	636.00	76.88	0.00	0.00	17.00	3.148	0.00	0.00	10.65	29.00	0.00	14400.00	47880.00	0.00
Max	36*	61.31	6234.00	78.00	16.85	34772.00	0.00	29877.00	2100.00	0.00	0.00	0.00	254.00	23.20	636.00	76.80	0.00	0.00	15.00	2.778	0.00	0.00	11.27	32.00	0.00	14460.00	47880.00	0.00
Case 6																												
Mean	1	60.37	6709.40	71.80	31.31	4344.50	0.00	32.10	0.00	0.00	0.00	0.00	191.80	15.22	696.00	84.78	0.00	0.00	21.20	5.889	0.00	0.00	12.10	29.80	0.00	10214.00	56880.00	0.00
Min	1	60.47	6702.00	74.00	32.48	4346.00	0.00	38.00	0.00	0.00	0.00	0.00	190.00	15.13	696.00	84.87	0.00	0.00	21.00	5.833	0.00	0.00	13.62	29.00	0.00	10140.00	56880.00	0.00
Max	1	60.29	6712.00	75.00	39.11	4343.00	0.00	28.00	0.00	0.00	0.00	0.00	192.00	15.26	696.00	84.74	0.00	0.00	21.00	5.833	0.00	0.00	12.58	33.00	0.00	10240.00	56880.00	0.00
Mean	12	60.37	6704.40	74.20	33.52	44717.40	0.00	352.00	0.00	0.00	0.00	0.00	192.40	15.15	696.00	84.76	0.00	0.00	21.50	5.972	0.00	0.00	11.80	28.00	0.00	10164.00	56880.00	0.00
Min	12	60.48	6702.00	72.00	56.24	43945.00	0.00	366.00	0.00	0.00	0.00	0.00	190.00	15.12	696.00	84.79	0.00	0.00	25.00	6.944	0.00	0.00	11.73	24.00	0.00	10140.00	56880.00	0.00
Max	12	60.28	6708.00	69.00	56.92	46368.00	0.00	339.00	0.00	0.00	0.00	0.00	188.00	15.20	696.00	84.74	0.00	0.00	20.00	5.556	0.00	0.00	11.62	24.00	0.00	10200.00	56880.00	0.00
Mean	36	70.89	6704.00	72.60	45.51	54024.50	0.00	451.10	0.00	0.00	0.00	0.00	192.00	15.13	696.00	84.68	0.00	0.00	21.30	5.917	0.00	0.00	12.13	31.90	0.00	10160.00	56880.00	0.00
Min	36	66.74	6700.00	73.00	57.95	51936.00	0.00	411.00	0.00	0.00	0.00	0.00	196.00	15.06	696.00	84.67	0.00	0.00	20.00	5.556	0.00	0.00	13.73	32.00	0.00	10120.00	56880.00	0.00
Max	36	70.40	6708.00	73.00	47.80	54608.00	0.00	434.00	0.00	0.00	0.00	0.00	188.00	15.21	696.00	84.79	0.00	0.00	22.00	6.111	0.00	0.00	12.92	34.00	0.00	10200.00	56880.00	0.00
Mean	36*	64.92	6705.40	72.60	40.82	47379.80	0.00	370.30	0.00	0.00	0.00	0.00	191.00	15.17	696.00	84.83	0.00	0.00	21.00	5.833	0.00	0.00	12.55	30.60	0.00	10174.00	56880.00	0.00
Min	36*	77.10	6702.00	72.00	39.92	48130.00	0.00	407.00	0.00	0.00	0.00	0.00	190.00	15.13	696.00	84.87	0.00	0.00	20.00	5.556	0.00	0.00	13.50	24.00	0.00	10140.00	56880.00	0.00
Max	36*	75.00	6708.00	73.00	34.93	51373.00	0.00	408.00	0.00	0.00	0.00	0.00	188.00	15.21	696.00	84.79	0.00	0.00	22.00	6.111	0.00	0.00	12.65	30.00	0.00	10200.00	56880.00	0.00

Table E.11: Results of the best results of GBN network cases 4, 5 and 6, for 60 seconds.

OPERATIONS	COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
	$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
Case 7																												
Mean	1	60.42	6630.00	80.00	28.55	2091.10	0.00	2091.10	1385.50	0.00	0.00	0.00	569.20	49.68	388.00	50.32	0.00	0.00	29.10	2.343	0.00	0.00	9.52	29.60	0.00	32940.00	33360.00	0.00
Min	1	60.30	6622.00	80.00	53.54	2082.00	0.00	2082.00	1378.00	0.00	0.00	0.00	574.00	49.62	388.00	50.38	0.00	0.00	28.00	2.254	0.00	0.00	8.96	28.00	0.00	32860.00	33360.00	0.00
Max	1	60.53	6638.00	80.00	9.33	2104.00	0.00	2104.00	1410.00	0.00	0.00	0.00	574.00	49.74	388.00	50.26	0.00	0.00	35.00	2.818	0.00	0.00	7.42	22.00	0.00	33020.00	33360.00	0.00
Mean	12	60.49	6613.40	80.00	40.76	20602.00	0.00	20602.00	13612.90	0.00	0.00	0.00	564.60	49.42	388.00	50.30	0.00	0.00	27.70	2.230	0.00	0.00	9.22	30.40	0.00	32774.00	33360.00	0.00
Min	12	60.40	6604.00	80.00	47.46	20478.00	0.00	20478.00	13481.00	0.00	0.00	0.00	564.00	49.26	388.00	50.29	0.00	0.00	23.00	1.852	0.00	0.00	10.00	32.00	0.00	32680.00	33360.00	0.00
Max	12	60.62	6626.00	80.00	30.84	19638.00	0.00	19638.00	13024.00	0.00	0.00	0.00	562.00	49.56	388.00	50.26	0.00	0.00	32.00	2.576	0.00	0.00	8.08	31.00	0.00	32900.00	33360.00	0.00
Mean	36	72.94	6614.80	80.00	28.77	23996.10	0.00	23996.10	15829.50	0.00	0.00	0.00	563.60	49.40	388.00	50.26	0.00	0.00	28.00	2.254	0.00	0.00	10.05	32.00	0.00	32788.00	33360.00	0.00
Min	36	69.33	6606.00	80.00	46.36	22625.00	0.00	22625.00	14938.00	0.00	0.00	0.00	558.00	49.35	388.00	50.35	0.00	0.00	27.00	2.174	0.00	0.00	12.19	42.00	0.00	32700.00	33360.00	0.00
Max	36	66.85	6624.00	80.00	29.30	22359.00	0.00	22359.00	14646.00	0.00	0.00	0.00	568.00	49.47	388.00	50.20	0.00	0.00	28.00	2.254	0.00	0.00	10.27	33.00	0.00	32880.00	33360.00	0.00
Mean	36*	61.64	6615.60	80.00	20.98	21411.60	0.00	21411.60	14130.40	0.00	0.00	0.00	566.00	49.57	388.00	50.43	0.00	0.00	29.20	2.351	0.00	0.00	9.81	29.90	0.00	32796.00	33360.00	0.00
Min	36*	61.53	6606.00	80.00	28.81	20399.00	0.00	20399.00	13460.00	0.00	0.00	0.00	574.00	49.50	388.00	50.50	0.00	0.00	28.00	2.254	0.00	0.00	10.27	25.00	0.00	32700.00	33360.00	0.00
Max	36*	61.15	6620.00	80.00	33.32	20730.00	0.00	20730.00	13695.00	0.00	0.00	0.00	564.00	49.61	388.00	50.39	0.00	0.00	26.00	2.093	0.00	0.00	9.92	27.00	0.00	32840.00	33360.00	0.00
Case 8																												
Mean	1	60.47	7272.60	80.00	28.39	1351.40	0.00	1351.40	309.70	0.00	0.00	0.00	293.80	23.85	734.00	76.15	0.00	0.00	29.40	4.734	0.00	0.00	6.73	24.90	0.00	17346.00	55380.00	0.00
Min	1	60.31	7260.00	80.00	16.72	1353.00	0.00	1353.00	314.00	0.00	0.00	0.00	290.00	23.72	734.00	76.28	0.00	0.00	29.00	4.670	0.00	0.00	4.73	16.00	0.00	17220.00	55380.00	0.00
Max	1	60.56	7284.00	80.00	54.33	1318.00	0.00	1318.00	284.00	0.00	0.00	0.00	298.00	23.97	734.00	76.03	0.00	0.00	29.00	4.670	0.00	0.00	5.35	21.00	0.00	17460.00	55380.00	0.00
Mean	12	60.57	7260.80	80.00	23.21	10441.90	0.00	10441.50	2418.90	0.00	0.00	0.00	295.60	23.68	734.00	76.12	0.00	0.00	27.70	4.461	0.00	0.00	6.73	24.60	0.00	17228.00	55380.00	0.00
Min	12	60.43	7254.00	80.00	6.76	10065.00	0.00	10065.00	2294.00	0.00	0.00	0.00	292.00	23.56	734.00	76.03	0.00	0.00	25.00	4.026	0.00	0.00	6.08	23.00	0.00	17160.00	55380.00	0.00
Max	12	60.51	7264.00	80.00	56.25	12190.00	0.00	12190.00	2905.00	0.00	0.00	0.00	294.00	23.72	734.00	76.11	0.00	0.00	29.00	4.670	0.00	0.00	8.08	27.00	0.00	17260.00	55380.00	0.00
Mean	36	71.78	7253.16	80.00	28.25	14704.40	0.00	14703.80	3389.20	0.00	0.00	0.00	294.20	23.53	734.00	76.02	0.10	0.01	26.50	4.267	0.00	0.00	7.33	25.00	0.00	17142.00	55380.00	9.60
Min	36	69.01	7228.00	80.00	3.85	13948.00	0.00	13948.00	3221.00	0.00	0.00	0.00	290.00	23.23	734.00	76.13	0.00	0.00	27.00	4.348	0.00	0.00	6.73	24.00	0.00	16900.00	55380.00	0.00
Max	36	74.63	7262.00	80.00	22.28	14890.00	0.00	14889.00	3408.00	0.00	0.00	0.00	300.00	23.63	734.00	75.90	0.00	0.00	25.00	4.026	0.00	0.00	7.23	23.00	0.00	17240.00	55380.00	0.00
Mean	36*	64.05	7258.00	80.00	25.62	14672.60	0.00	14671.90	3404.50	0.00	0.00	0.00	294.40	23.70	734.00	76.30	0.00	0.00	26.40	4.251	0.00	0.00	7.44	26.30	0.00	17200.00	55380.00	0.00
Min	36*	61.06	7246.00	80.00	34.12	14055.00	0.00	14054.00	3238.00	0.00	0.00	0.00	284.00	23.57	734.00	76.43	0.00	0.00	26.00	4.187	0.00	0.00	6.88	26.00	0.00	17080.00	55380.00	0.00
Max	36*	61.14	7270.00	80.00	22.31	14325.00	0.00	14325.00	3387.00	0.00	0.00	0.00	292.00	23.82	734.00	76.18	0.00	0.00	27.00	4.348	0.00	0.00	7.08	25.00	0.00	17320.00	55380.00	0.00
Case 9																												
Mean	1	60.46	7970.20	80.00	28.90	740.40	0.00	740.40	0.20	0.00	0.00	0.00	241.60	23.20	729.20	76.80	0.00	0.00	38.20	9.227	0.00	0.00	10.33	37.90	0.00	18490.00	61212.00	0.00
Min	1	60.36	7958.00	80.00	13.01	747.00	0.00	747.00	0.00	0.00	0.00	0.00	240.00	23.62	722.00	76.38	0.00	0.00	34.00	8.213	0.00	0.00	10.12	39.00	0.00	18800.00	60780.00	0.00
Max	1	60.62	7980.00	80.00	8.92	733.00	0.00	733.00	0.00	0.00	0.00	0.00	248.00	23.38	728.00	76.62	0.00	0.00	38.00	9.179	0.00	0.00	12.15	45.00	0.00	18660.00	61140.00	0.00
Mean	12	60.63	7944.80	80.00	31.34	7614.10	0.00	7615.70	1.60	0.00	0.00	0.00	239.00	22.51	734.20	77.18	0.00	0.00	38.00	9.179	0.00	0.00	9.87	37.40	0.00	17936.00	61512.00	0.00
Min	12	60.56	7928.00	80.00	24.74	7729.00	0.00	7729.00	1.00	0.00	0.00	0.00	234.00	22.43	732.00	76.92	0.00	0.00	32.00	7.729	0.00	0.00	9.92	36.00	0.00	17900.00	61380.00	0.00
Max	12	60.78	7956.00	80.00	51.25	7758.00	0.00	7758.00	4.00	0.00	0.00	0.00	246.00	23.60	722.00	76.38	0.00	0.00	33.00	7.971	0.00	0.00	9.65	32.00	0.00	18780.00	60780.00	0.00
Mean	36	72.00	7943.96	80.00	32.88	9230.60	0.00	9208.50	2.20	0.00	0.00	0.00	232.60	22.21	738.00	77.50	0.10	0.01	35.10	8.478	0.00	0.00	10.18	39.90	0.00	17690.00	61740.00	9.60
Min	36	74.43	7926.00	80.00	50.65	9296.00	0.00	9296.00	3.00	0.00	0.00	0.00	232.00	21.92	738.00	77.25	0.00	0.00	32.00	7.729	0.00	0.00	10.35	42.00	0.00	17520.00	61740.00	0.00
Max	36	72.96	7956.00	80.00	48.27	8621.00	0.00	8621.00	2.00	0.00	0.00	0.00	240.00	23.15	728.00	76.85	0.00	0.00	36.00	8.696	0.00	0.00	10.69	39.00	0.00	18420.00	61140.00	0.00
Mean	36*	62.67	7942.40	80.00	43.02	8086.70	0.00	8086.70	2.60	0.00	0.00	0.00	236.60	22.48	735.20	77.52	0.00	0.00	36.20	8.744	0.00	0.00	9.67	37.20	0.00	17852.00	61572.00	0.00
Min	36*	61.23	7924.00	80.00	32.31	7850.00	0.00	7850.00	4.00	0.00	0.00	0.00	228.00	21.78	742.00	78.22	0.00	0.00	42.00	10.145	0.00	0.00	11.88	44.00	0.00	17260.00	61980.00	0.00
Max	36*	61.12	7956.00	80.00	42.73	7932.00	0.00	7932.00	3.00	0.00	0.00	0.00	236.00	22.55	736.00	77.45	0.00	0.00	35.00	8.454	0.00	0.00	8.35	40.00	0.00	17940.00	61620.00	0.00

Table E.12: Results of the best results of GBN network cases 7, 8 and 9, for 60 seconds.

E.4 NSF best results for 60 seconds.

Symbol	Name
$\#T$	Number of Threads
t_E	Time of Execution
C	Best Cost Solution found
CA	Highest Channel Assigned
t_{sol}	Found Solution Time
$\#i$	Number of Iterations
$\#IS$	Number of Invalid Solutions
$\#G_U$	Number of Greedy Solutions Unfeasible
$\#LS_U$	Number of Local Search Solutions Unfeasible
UD	Unfeasible Degree
$\#IM$	Number of Invert Multiplex used
C_{IM}	Cost % of Invert Multiplex
$\#MX$	Number of Muxponders placed
C_{MX}	Cost % of Muxponders
$\#TX$	Number of Transponders placed
C_{TX}	Cost % of Transponders
$\#3R$	Number of $3R$ regenerators placed
C_{3R}	Cost % of $3R$ regenerators
$\#10$	Number of Multi-Hop Grooming of $10Gb/s$
$\%10$	Traffic % of Multi-Hop Grooming of $10Gb/s$
$\#40$	Number of Multi-hop Grooming of $40Gb/s$
$\%40$	Traffic % of Multi-hop Grooming of $40Gb/s$
$\bar{m}F$	Average Fragmentation at Channel Assigned
MF	Max Fragmentation at Channel Assigned
C_{IM}	Cost of Invert Multiplexers
C_{MX}	Cost of Multiplexers
C_{TX}	Cost of Transponders
C_{3R}	Cost of $3R$ regenerators

Table E.13: Header symbols and their description.

OPERATIONS	COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
	$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
Case 1																												
Mean	1	60.18	4440.40	59.00	11.82	25654.30	0.00	0.00	0.00	0.00	14.00	6.31	300.00	34.86	126.00	22.30	157.00	36.54	7.90	1.317	0.00	0.00	4.46	28.30	2800.00	15480.00	9900.00	16224.00
Min	1	60.22	4440.40	59.00	1.79	25678.00	0.00	0.00	0.00	0.00	14.00	6.31	300.00	34.86	126.00	22.30	157.00	36.54	7.00	1.167	0.00	0.00	4.75	29.00	2800.00	15480.00	9900.00	16224.00
Max	1	60.12	4440.40	59.00	24.62	25621.00	0.00	0.00	0.00	0.00	14.00	6.31	300.00	34.86	126.00	22.30	157.00	36.54	7.00	1.167	0.00	0.00	3.70	28.00	2800.00	15480.00	9900.00	16224.00
Mean	12	60.19	4440.40	59.00	1.29	238823.70	0.00	0.00	0.00	0.00	14.00	6.31	300.00	34.86	126.00	22.30	157.00	36.54	7.10	1.183	0.00	0.00	4.48	26.80	2800.00	15480.00	9900.00	16224.00
Min	12	60.15	4440.40	59.00	0.02	242412.00	0.00	0.00	0.00	0.00	14.00	6.31	300.00	34.86	126.00	22.30	157.00	36.54	6.00	1.000	0.00	0.00	4.80	29.00	2800.00	15480.00	9900.00	16224.00
Max	12	60.15	4440.40	59.00	2.68	250100.00	0.00	0.00	0.00	0.00	14.00	6.31	300.00	34.86	126.00	22.30	157.00	36.54	7.00	1.167	0.00	0.00	4.15	29.00	2800.00	15480.00	9900.00	16224.00
Mean	36	70.17	4440.24	59.00	2.35	302366.80	0.00	0.00	0.00	0.00	14.00	6.31	300.80	34.88	126.00	22.30	157.20	36.52	7.90	1.317	0.00	0.00	4.49	28.40	2800.00	15488.00	9900.00	16214.40
Min	36	62.76	4438.80	59.00	14.71	277932.00	0.00	0.00	0.00	0.00	14.00	6.31	308.00	35.04	126.00	22.30	159.00	36.32	12.00	2.000	0.00	0.00	4.90	29.00	2800.00	15560.00	9900.00	16128.00
Max	36	69.20	4440.40	59.00	3.00	289600.00	0.00	0.00	0.00	0.00	14.00	6.31	300.00	34.86	126.00	22.30	157.00	36.54	8.00	1.333	0.00	0.00	4.60	28.00	2800.00	15480.00	9900.00	16224.00
Mean	36*	71.21	4440.24	59.10	5.98	297902.20	0.00	0.00	0.00	0.00	14.00	6.31	300.80	34.88	126.00	22.30	157.20	36.52	7.10	1.183	0.00	0.00	4.54	25.60	2800.00	15488.00	9900.00	16214.40
Min	36*	70.87	4438.80	60.00	43.26	296947.00	0.00	0.00	0.00	0.00	14.00	6.31	308.00	35.05	126.00	22.30	159.00	36.33	11.00	1.833	0.00	0.00	4.70	26.00	2800.00	15560.00	9900.00	16128.00
Max	36*	74.22	4440.40	59.00	5.21	307934.00	0.00	0.00	0.00	0.00	14.00	6.31	300.00	34.86	126.00	22.30	157.00	36.54	6.00	1.000	0.00	0.00	4.75	20.00	2800.00	15480.00	9900.00	16224.00
Case 2																												
Mean	1	60.19	4895.52	61.90	30.20	19515.60	0.00	0.00	0.00	0.00	16.00	6.54	151.60	16.63	334.00	47.19	140.10	29.65	10.70	3.567	0.00	0.00	5.23	29.40	3200.00	8140.00	23100.00	14515.20
Min	1	60.14	4892.00	66.00	49.05	19530.00	0.00	0.00	0.00	0.00	16.00	6.54	158.00	16.80	334.00	47.22	141.00	29.44	11.00	3.667	0.00	0.00	5.95	33.00	3200.00	8220.00	23100.00	14400.00
Max	1	60.14	4902.00	61.00	1.58	19516.00	0.00	0.00	0.00	0.00	16.00	6.53	152.00	16.48	334.00	47.12	142.00	29.87	8.00	2.667	0.00	0.00	6.65	35.00	3200.00	8080.00	23100.00	14640.00
Mean	12	60.21	4888.32	61.40	28.34	185758.20	0.00	0.00	0.00	0.00	16.00	6.54	152.40	16.58	334.00	47.19	140.80	29.55	11.40	3.800	0.00	0.00	5.06	28.50	3200.00	8116.00	23100.00	14467.20
Min	12	60.26	4882.80	62.00	6.07	177795.00	0.00	0.00	0.00	0.00	16.00	6.54	152.00	16.52	334.00	47.22	140.00	29.53	12.00	4.000	0.00	0.00	4.85	28.00	3200.00	8080.00	23100.00	14448.00
Max	12	60.25	4892.40	61.00	35.71	193367.00	0.00	0.00	0.00	0.00	16.00	6.54	152.00	16.50	334.00	47.18	141.00	29.70	9.00	3.000	0.00	0.00	4.55	29.00	3200.00	8080.00	23100.00	14544.00
Mean	36	72.01	4886.72	61.60	34.01	237240.40	0.00	0.00	0.00	0.00	16.00	6.53	153.20	16.59	334.00	47.16	141.00	29.49	11.70	3.900	0.00	0.00	5.46	30.50	3200.00	8124.00	23100.00	14443.20
Min	36	71.99	4882.80	62.00	10.84	235211.00	0.00	0.00	0.00	0.00	16.00	6.53	152.00	16.48	334.00	47.12	140.00	29.47	13.00	4.333	0.00	0.00	5.95	31.00	3200.00	8080.00	23100.00	14448.00
Max	36	76.55	4892.00	64.00	49.25	251361.00	0.00	0.00	0.00	0.00	16.00	6.53	158.00	16.79	334.00	47.17	141.00	29.40	13.00	4.333	0.00	0.00	5.55	30.00	3200.00	8220.00	23100.00	14400.00
Mean	36*	68.18	4887.08	61.50	22.86	215791.50	0.00	0.00	0.00	0.00	16.00	6.55	152.60	16.56	334.00	47.27	141.20	29.62	11.50	3.833	0.00	0.00	5.46	30.30	3200.00	8094.00	23100.00	14476.80
Min	36*	68.53	4882.80	62.00	11.65	223249.00	0.00	0.00	0.00	0.00	16.00	6.55	152.00	16.55	334.00	47.31	140.00	29.59	13.00	4.333	0.00	0.00	5.95	31.00	3200.00	8080.00	23100.00	14448.00
Max	36*	60.96	4892.40	62.00	9.14	201528.00	0.00	0.00	0.00	0.00	16.00	6.54	152.00	16.52	334.00	47.22	141.00	29.73	10.00	3.333	0.00	0.00	5.40	31.00	3200.00	8080.00	23100.00	14544.00
Case 3																												
Mean	1	60.20	5542.28	80.00	22.99	19886.40	0.00	19886.40	0.00	0.00	24.00	8.66	102.60	10.09	356.00	47.63	172.00	33.61	7.20	3.600	0.00	0.00	5.82	35.60	4800.00	5594.00	26400.00	18628.80
Min	1	60.25	5535.60	80.00	1.09	19908.00	0.00	19908.00	0.00	0.00	24.00	8.67	102.00	10.08	356.00	47.69	171.00	33.56	8.00	4.000	0.00	0.00	5.55	34.00	4800.00	5580.00	26400.00	18576.00
Max	1	60.25	5545.20	80.00	20.81	19903.00	0.00	19903.00	0.00	0.00	24.00	8.66	102.00	10.06	356.00	47.61	172.00	33.67	6.00	3.000	0.00	0.00	4.90	30.00	4800.00	5580.00	26400.00	18672.00
Mean	12	60.21	5534.80	80.00	28.18	192225.80	0.00	192225.80	0.00	0.00	24.00	8.66	104.40	10.05	356.00	47.63	171.90	33.52	7.60	3.800	0.00	0.00	5.09	33.40	4800.00	5572.00	26400.00	18576.00
Min	12	60.24	5528.80	80.00	34.14	192635.00	0.00	192635.00	0.00	0.00	24.00	8.67	108.00	10.05	356.00	47.70	172.00	33.48	8.00	4.000	0.00	0.00	4.90	38.00	4800.00	5560.00	26400.00	18528.00
Max	12	60.26	5538.40	80.00	20.37	200802.00	0.00	200802.00	0.00	0.00	24.00	8.66	108.00	10.03	356.00	47.63	173.00	33.60	10.00	5.000	0.00	0.00	4.65	34.00	4800.00	5560.00	26400.00	18624.00
Mean	36	71.22	5534.84	80.00	21.82	241887.40	0.00	241887.40	0.00	0.00	24.00	8.65	103.80	10.11	356.00	47.59	171.40	33.43	8.00	4.000	0.00	0.00	5.06	34.00	4800.00	5606.00	26400.00	18542.40
Min	36	72.10	5526.00	80.00	9.44	242243.00	0.00	242243.00	0.00	0.00	24.00	8.66	102.00	10.06	356.00	47.61	170.00	33.32	6.00	3.000	0.00	0.00	5.75	35.00	4800.00	5580.00	26400.00	18480.00
Max	36	73.80	5542.80	80.00	57.50	255036.00	0.00	255036.00	0.00	0.00	24.00	8.66	98.00	10.28	356.00	47.62	169.00	33.42	9.00	4.500	0.00	0.00	4.25	34.00	4800.00	5700.00	26400.00	18528.00
Mean	36*	67.02	5538.52	80.00	29.26	217536.00	0.00	217536.00	0.00	0.00	24.00	8.67	103.80	10.09	356.00	47.67	172.10	33.57	7.70	3.850	0.00	0.00	4.75	34.10	4800.00	5590.00	26400.00	18595.20
Min	36*	61.01	5534.40	80.00	32.18	209258.00	0.00	209258.00	0.00	0.00	24.00	8.67	104.00	9.97	356.00	47.70	173.00	33.65	6.00	3.000	0.00	0.00	5.20	37.00	4800.00	5520.00	26400.00	18624.00
Max	36*	68.62	5544.00	80.00	4.51	205131.00	0.00	205131.00	0.00	0.00	24.00	8.66	104.00	9.96	356.00	47.62	174.00	33.77	4.00	2.000	0.00	0.00	5.05	37.00	4800.00	5520.00	26400.00	18720.00

Table E.14: Results of the best results of NSF network cases 1, 2 and 3, for 60 seconds.

OPERATIONS	COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
	$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
Case 4																												
Mean	1	60.24	5402.40	59.60	24.11	7334.30	0.00	0.00	0.00	0.00	20.00	7.40	407.20	37.95	162.00	23.32	164.40	31.32	18.60	2.385	0.00	0.00	4.18	30.90	4000.00	20504.00	12600.00	16920.00
Min	1	60.29	5394.80	60.00	54.51	7310.00	0.00	0.00	0.00	0.00	20.00	7.41	410.00	38.00	162.00	23.36	165.00	31.23	20.00	2.564	0.00	0.00	4.80	32.00	4000.00	20500.00	12600.00	16848.00
Max	1	60.29	5406.40	60.00	12.68	7372.00	0.00	0.00	0.00	0.00	20.00	7.40	404.00	37.96	162.00	23.31	163.00	31.34	15.00	1.923	0.00	0.00	4.40	33.00	4000.00	20520.00	12600.00	16944.00
Mean	12	60.24	5393.08	59.60	37.04	72078.80	0.00	0.00	0.00	0.00	19.80	7.33	404.80	37.79	162.20	23.38	164.30	31.33	19.00	2.436	0.00	0.00	4.06	31.50	3960.00	20416.00	12630.00	16924.80
Min	12	60.20	5385.60	60.00	36.36	71750.00	0.00	0.00	0.00	0.00	20.00	7.40	404.00	37.66	162.00	23.31	164.00	31.25	23.00	2.949	0.00	0.00	4.10	28.00	4000.00	20360.00	12600.00	16896.00
Max	12	60.33	5395.60	61.00	43.04	71427.00	0.00	0.00	0.00	0.00	20.00	7.41	406.00	37.89	162.00	23.33	164.00	31.29	20.00	2.564	0.00	0.00	3.60	36.00	4000.00	20460.00	12600.00	16896.00
Mean	36	70.50	5387.88	59.60	28.12	88231.80	0.00	0.00	0.00	0.00	20.00	7.40	404.20	37.73	162.00	23.30	163.80	31.21	18.80	2.410	0.00	0.00	4.06	30.60	4000.00	20402.00	12600.00	16876.80
Min	36	66.08	5377.20	59.00	15.68	83952.00	0.00	0.00	0.00	0.00	20.00	7.39	402.00	37.71	162.00	23.27	161.00	30.93	24.00	3.077	0.00	0.00	3.75	36.00	4000.00	20420.00	12600.00	16752.00
Max	36	72.15	5395.20	60.00	31.71	87835.00	0.00	0.00	0.00	0.00	20.00	7.41	404.00	37.70	162.00	23.33	165.00	31.46	19.00	2.436	0.00	0.00	3.75	32.00	4000.00	20360.00	12600.00	16992.00
Mean	36*	64.64	5390.16	59.80	27.27	80686.10	0.00	0.00	0.00	0.00	19.80	7.35	405.40	37.81	162.20	23.43	164.80	31.41	18.80	2.410	0.00	0.00	3.86	28.30	3960.00	20382.00	12630.00	16929.60
Min	36*	60.98	5384.80	60.00	13.14	79613.00	0.00	0.00	0.00	0.00	20.00	7.43	408.00	37.88	162.00	23.40	165.00	31.29	20.00	2.564	0.00	0.00	4.00	29.00	4000.00	20400.00	12600.00	16848.00
Max	36*	60.96	5395.20	60.00	44.38	78687.00	0.00	0.00	0.00	0.00	20.00	7.41	404.00	37.74	162.00	23.35	165.00	31.49	16.00	2.051	0.00	0.00	4.25	32.00	4000.00	20360.00	12600.00	16992.00
Case 5																												
Mean	1	60.25	6798.16	80.00	32.10	8628.00	0.00	3854.70	149.80	0.00	16.40	4.82	192.00	15.62	438.80	45.29	217.40	34.26	11.70	3.000	0.00	0.00	7.82	44.70	3280.00	10620.00	30792.00	23289.60
Min	1	60.18	6771.20	80.00	43.56	8664.00	0.00	3881.00	147.00	0.00	16.00	4.73	194.00	16.39	432.00	44.93	214.00	33.96	10.00	2.564	0.00	0.00	7.85	47.00	3200.00	11100.00	30420.00	22992.00
Max	1	60.34	6819.60	80.00	32.73	8652.00	0.00	3851.00	159.00	0.00	16.00	4.69	184.00	15.37	440.00	45.31	219.00	34.63	9.00	2.308	0.00	0.00	7.80	45.00	3200.00	10480.00	30900.00	23616.00
Mean	12	60.27	6770.04	79.80	28.88	82714.40	0.00	36782.00	1462.00	0.00	17.20	5.06	191.80	15.42	438.80	45.18	217.20	33.90	11.10	2.846	0.00	0.00	8.11	45.80	3440.00	10486.00	30720.00	23054.40
Min	12	60.20	6754.80	80.00	47.55	84738.00	0.00	37743.00	1520.00	0.00	18.00	5.29	194.00	15.44	438.00	44.99	217.00	33.59	13.00	3.333	0.00	0.00	8.15	43.00	3600.00	10500.00	30600.00	22848.00
Max	12	60.33	6786.80	79.00	20.69	83739.00	0.00	37199.00	1455.00	0.00	18.00	5.30	186.00	15.57	438.00	45.03	218.00	33.98	14.00	3.590	0.00	0.00	8.45	45.00	3600.00	10580.00	30600.00	23088.00
Mean	36	72.21	6779.04	80.00	29.23	104076.10	0.00	46410.10	1820.90	0.00	16.40	4.81	192.40	15.47	438.80	45.18	216.80	34.00	10.60	2.718	0.00	0.00	7.88	47.20	3280.00	10544.00	30792.00	23174.40
Min	36	75.10	6770.80	80.00	20.95	107541.00	0.00	47947.00	1897.00	0.00	16.00	4.68	188.00	15.39	440.00	45.20	215.00	33.77	13.00	3.333	0.00	0.00	8.10	45.00	3200.00	10520.00	30900.00	23088.00
Max	36	77.14	6787.20	80.00	52.63	109007.00	0.00	48705.00	1851.00	0.00	18.00	5.27	196.00	15.29	438.00	44.82	221.00	34.03	9.00	2.308	0.00	0.00	8.75	48.00	3600.00	10440.00	30600.00	23232.00
Mean	36*	64.30	6777.40	79.80	32.40	86964.10	0.00	38723.10	1559.20	0.00	16.20	4.78	194.40	15.50	439.80	45.55	217.10	34.17	12.10	3.103	0.00	0.00	7.92	44.80	3240.00	10504.00	30870.00	23160.00
Min	36*	66.85	6761.20	80.00	19.20	93138.00	0.00	41353.00	1656.00	0.00	18.00	5.32	194.00	15.77	438.00	45.26	216.00	33.65	15.00	3.846	0.00	0.00	8.20	45.00	3600.00	10660.00	30600.00	22752.00
Max	36*	61.06	6790.00	80.00	52.62	87334.00	0.00	39017.00	1622.00	0.00	12.00	3.53	200.00	15.43	444.00	46.39	215.00	34.64	13.00	3.333	0.00	0.00	6.55	41.00	2400.00	10480.00	31500.00	23520.00
Case 6																												
Mean	1	60.27	7358.76	79.20	28.96	8071.70	0.00	1657.60	0.00	0.00	26.40	7.18	138.60	9.87	467.60	47.62	240.40	35.33	15.20	5.846	0.00	0.00	5.60	28.90	5280.00	7266.00	35040.00	26001.60
Min	1	60.20	7344.40	79.00	22.43	8029.00	0.00	1672.00	0.00	0.00	28.00	7.62	138.00	9.83	466.00	47.38	239.00	35.16	15.00	5.769	0.00	0.00	5.70	23.00	5600.00	7220.00	34800.00	25824.00
Max	1	60.20	7372.40	79.00	40.89	8039.00	0.00	1703.00	0.00	0.00	28.00	7.60	142.00	9.85	466.00	47.20	243.00	35.35	15.00	5.769	0.00	0.00	5.85	36.00	5600.00	7260.00	34800.00	26064.00
Mean	12	60.28	7345.80	78.80	35.21	77706.60	0.00	15968.10	0.00	0.00	28.00	7.61	134.60	9.86	466.00	47.26	238.90	35.04	14.50	5.577	0.00	0.00	6.10	29.80	5600.00	7258.00	34800.00	25800.00
Min	12	60.20	7331.20	78.00	38.31	76497.00	0.00	15682.00	0.00	0.00	28.00	7.60	136.00	9.87	466.00	47.20	237.00	34.77	16.00	6.154	0.00	0.00	6.65	34.00	5600.00	7280.00	34800.00	25632.00
Max	12	60.36	7356.40	80.00	47.86	79020.00	0.00	16166.00	0.00	0.00	28.00	7.60	134.00	9.97	466.00	47.25	239.00	35.06	18.00	6.923	0.00	0.00	5.95	32.00	5600.00	7340.00	34800.00	25824.00
Mean	36	70.44	7347.24	79.20	27.47	95229.30	0.00	19557.40	0.00	0.00	27.60	7.50	137.40	9.85	466.40	47.33	239.60	35.08	14.80	5.692	0.00	0.00	5.91	30.40	5520.00	7254.00	34860.00	25838.40
Min	36	74.68	7339.60	80.00	44.18	101329.00	0.00	20896.00	0.00	0.00	28.00	7.61	138.00	9.81	466.00	47.26	240.00	35.01	12.00	4.615	0.00	0.00	6.90	30.00	5600.00	7220.00	34800.00	25776.00
Max	36	66.21	7355.20	80.00	30.79	90949.00	0.00	18845.00	0.00	0.00	28.00	7.60	136.00	9.89	466.00	47.26	241.00	35.13	16.00	6.154	0.00	0.00	5.10	28.00	5600.00	7280.00	34800.00	25872.00
Mean	36*	68.48	7345.92	78.70	35.68	87115.10	0.00	17906.80	0.00	0.00	27.60	7.51	138.00	9.85	466.40	47.45	239.20	35.18	14.70	5.654	0.00	0.00	5.81	30.60	5520.00	7236.00	34860.00	25843.20
Min	36*	69.23	7340.80	78.00	30.25	94745.00	0.00	19475.00	0.00	0.00	28.00	7.63	136.00	9.92	466.00	47.41	238.00	35.05	16.00	6.154	0.00	0.00	5.90	35.00	5600.00	7280.00	34800.00	25728.00
Max	36*	61.11	7354.00	78.00	45.13	78688.00	0.00	16124.00	0.00	0.00	28.00	7.61	138.00	9.82	466.00	47.32	240.00	35.25	14.00	5.385	0.00	0.00	5.95	33.00	5600.00	7220.00	34800.00	25920.00

Table E.15: Results of the best results of NSF network cases 4, 5 and 6, for 60 seconds.

OPERATIONS	COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
	$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
Case 7																												
Mean	1	60.30	7857.80	80.00	32.19	2396.00	0.00	2396.00	431.40	0.00	16.60	4.23	500.40	34.65	221.40	22.79	257.50	38.33	30.60	3.018	0.00	0.00	5.14	36.70	3320.00	27228.00	17910.00	30120.00
Min	1	60.25	7822.40	80.00	26.50	2446.00	0.00	2446.00	460.00	0.00	22.00	5.62	498.00	34.90	216.00	21.86	254.00	37.62	28.00	2.761	0.00	0.00	6.60	43.00	4400.00	27300.00	17100.00	29424.00
Max	1	60.39	7910.00	80.00	29.42	2373.00	0.00	2373.00	410.00	0.00	16.00	4.05	502.00	34.36	222.00	22.76	260.00	38.84	25.00	2.465	0.00	0.00	4.95	45.00	3200.00	27180.00	18000.00	30720.00
Mean	12	60.35	7825.04	80.00	32.28	23912.00	0.00	23912.00	4307.90	0.00	16.40	4.17	500.00	34.60	221.60	22.82	252.60	37.93	32.50	3.205	0.00	0.00	4.83	34.60	3280.00	27208.00	17940.00	29822.40
Min	12	60.29	7799.20	80.00	48.05	22976.00	0.00	22976.00	4174.00	0.00	16.00	4.06	500.00	34.35	222.00	22.83	251.00	37.69	30.00	2.959	0.00	0.00	5.00	29.00	3200.00	27080.00	18000.00	29712.00
Max	12	60.31	7857.60	80.00	20.36	23809.00	0.00	23809.00	4406.00	0.00	14.00	3.56	506.00	34.85	224.00	23.29	258.00	38.30	35.00	3.452	0.00	0.00	4.00	33.00	2800.00	27380.00	18300.00	30096.00
Mean	36	72.60	7821.44	79.90	31.41	30123.00	0.00	30123.00	5473.50	0.00	18.60	4.71	495.00	34.41	219.40	22.29	253.90	37.60	32.40	3.195	0.00	0.00	4.56	35.50	3720.00	27182.00	17610.00	29702.40
Min	36	67.24	7791.20	80.00	44.15	27785.00	0.00	27785.00	4992.00	0.00	14.00	3.55	494.00	34.31	224.00	23.17	248.00	37.62	30.00	2.959	0.00	0.00	3.10	25.00	2800.00	27100.00	18300.00	29712.00
Max	36	70.70	7840.40	80.00	53.15	29595.00	0.00	29595.00	5333.00	0.00	20.00	5.09	502.00	34.78	218.00	22.13	258.00	37.73	39.00	3.846	0.00	0.00	5.00	29.00	4000.00	27340.00	17400.00	29664.00
Mean	36*	62.85	7824.08	80.00	28.65	25774.80	0.20	25774.80	4665.10	0.00	16.00	4.09	499.60	34.83	222.00	23.01	253.00	38.07	32.80	3.235	0.00	0.00	4.73	35.60	3200.00	27252.00	18000.00	29788.80
Min	36*	68.67	7806.80	80.00	53.55	26244.00	2.00	26244.00	4889.00	0.00	16.00	4.10	498.00	34.97	222.00	23.06	254.00	37.87	29.00	2.860	0.00	0.00	5.30	35.00	3200.00	27300.00	18000.00	29568.00
Max	36*	61.42	7838.40	80.00	10.36	24824.00	0.00	24824.00	4370.00	0.00	16.00	4.08	488.00	34.80	222.00	22.96	253.00	38.15	33.00	3.254	0.00	0.00	3.90	26.00	3200.00	27280.00	18000.00	29904.00
Case 8																												
Mean	1	60.32	8394.12	80.00	31.15	2371.30	0.00	2371.30	106.30	0.00	19.20	4.57	231.00	16.56	574.80	48.25	240.70	30.62	21.10	4.162	0.00	0.00	3.72	22.20	3840.00	13902.00	40500.00	25699.20
Min	1	60.23	8366.40	80.00	37.33	2378.00	0.00	2378.00	90.00	0.00	18.00	4.30	228.00	16.49	576.00	48.62	238.00	30.58	16.00	3.156	0.00	0.00	4.45	21.00	3600.00	13800.00	40680.00	25584.00
Max	1	60.23	8407.60	80.00	56.88	2361.00	0.00	2361.00	114.00	0.00	20.00	4.76	240.00	16.56	574.00	48.03	246.00	30.66	24.00	4.734	0.00	0.00	3.10	21.00	4000.00	13920.00	40380.00	25776.00
Mean	12	60.35	8374.72	80.00	24.13	23714.40	0.00	23714.40	1056.80	0.00	19.80	4.72	230.20	16.43	574.20	48.12	242.60	30.46	19.40	3.826	0.00	0.00	3.60	22.40	3960.00	13798.00	40410.00	25579.20
Min	12	60.45	8352.40	80.00	15.59	24374.00	0.00	24374.00	1008.00	0.00	20.00	4.76	228.00	16.42	574.00	48.04	240.00	30.15	21.00	4.142	0.00	0.00	5.00	32.00	4000.00	13800.00	40380.00	25344.00
Max	12	60.45	8389.20	80.00	31.78	23178.00	0.00	23178.00	1081.00	0.00	18.00	4.29	230.00	16.38	576.00	48.49	241.00	30.84	16.00	3.156	0.00	0.00	3.05	21.00	3600.00	13740.00	40680.00	25872.00
Mean	36	71.97	8370.28	80.00	33.89	29719.10	0.00	29719.10	1326.00	0.00	19.40	4.62	230.00	16.46	574.60	48.14	240.00	30.35	21.20	4.181	0.00	0.00	4.08	22.40	3880.00	13836.00	40470.00	25516.80
Min	36	72.32	8359.20	80.00	48.10	29861.00	0.00	29861.00	1318.00	0.00	20.00	4.77	222.00	16.47	574.00	48.13	239.00	30.27	22.00	4.339	0.00	0.00	4.25	21.00	4000.00	13820.00	40380.00	25392.00
Max	36	74.55	8379.20	80.00	54.90	30515.00	0.00	30515.00	1284.00	0.00	20.00	4.75	234.00	16.38	574.00	47.99	243.00	30.47	22.00	4.339	0.00	0.00	4.10	24.00	4000.00	13780.00	40380.00	25632.00
Mean	36*	66.93	8371.00	80.00	37.19	26367.30	0.00	26367.30	1183.10	0.00	19.80	4.73	228.40	16.55	574.20	48.27	240.60	30.45	21.10	4.162	0.00	0.00	4.11	25.00	3960.00	13852.00	40410.00	25488.00
Min	36*	67.38	8352.40	80.00	58.87	26013.00	0.00	26013.00	1157.00	0.00	20.00	4.79	228.00	16.52	574.00	48.35	240.00	30.34	21.00	4.142	0.00	0.00	5.00	32.00	4000.00	13800.00	40380.00	25344.00
Max	36*	61.37	8382.00	80.00	23.01	25910.00	0.00	25910.00	1163.00	0.00	20.00	4.77	232.00	16.70	574.00	48.17	241.00	30.35	19.00	3.748	0.00	0.00	4.35	26.00	4000.00	14000.00	40380.00	25440.00
Case 9																												
Mean	1	60.38	10209.60	80.00	36.93	1629.30	0.00	1629.30	730.60	0.00	23.20	4.54	205.20	15.95	545.20	41.47	288.10	37.54	26.60	7.870	0.20	0.08	1.94	14.40	4640.00	16280.00	42342.00	38328.00
Min	1	60.25	10032.80	80.00	30.74	1590.00	0.00	1590.00	698.00	0.00	26.00	5.18	200.00	16.15	540.00	41.09	290.00	37.37	25.00	7.396	0.00	0.00	2.45	19.00	5200.00	16200.00	41220.00	37488.00
Max	1	60.26	10326.40	80.00	51.51	1674.00	0.00	1674.00	757.00	0.00	24.00	4.65	198.00	15.38	558.00	42.18	288.00	37.79	27.00	7.988	1.00	0.39	1.40	17.00	4800.00	15880.00	43560.00	39024.00
Mean	12	55.28	10164.56	80.00	34.42	16761.40	0.00	16761.40	7682.60	0.00	22.60	4.40	201.40	15.70	547.00	41.38	283.60	36.72	27.70	8.195	0.00	0.00	2.37	15.90	4520.00	16136.00	42522.00	37737.60
Min	12	60.40	10063.20	80.00	18.00	17805.00	0.00	17805.00	8047.00	0.00	26.00	5.14	194.00	15.67	550.00	41.91	282.00	36.04	31.00	9.172	0.00	0.00	2.05	19.00	5200.00	15840.00	42360.00	36432.00
Max	12	61.39	10305.20	80.00	22.45	15939.00	0.00	15939.00	7356.00	0.00	26.00	4.99	212.00	16.35	536.00	40.17	289.00	37.25	29.00	8.580	0.00	0.00	4.30	27.00	5200.00	17040.00	41880.00	38832.00
Mean	36	76.30	10143.84	80.00	37.41	20331.00	0.00	20331.00	8510.30	0.00	24.80	4.82	200.20	15.56	546.60	41.04	281.60	36.59	28.50	8.432	0.00	0.00	2.14	13.40	4960.00	16018.00	42228.00	37646.40
Min	36	70.70	10087.60	80.00	40.93	21257.00	0.00	21257.00	9515.00	0.00	22.00	4.26	190.00	14.92	554.00	41.56	279.00	36.08	27.00	7.988	0.00	0.00	2.70	13.00	4400.00	15420.00	42960.00	37296.00
Max	36	75.53	10218.40	80.00	59.98	21670.00	0.00	21670.00	8616.00	0.00	26.00	5.09	212.00	16.25	540.00	40.87	280.00	37.02	27.00	7.988	0.00	0.00	2.55	11.00	5200.00	16600.00	41760.00	37824.00
Mean	36*	61.97	10103.32	80.00	37.43	18083.40	0.00	18083.40	8254.60	0.00	23.40	4.63	204.00	15.71	549.40	42.11	281.60	37.00	25.80	7.633	0.00	0.00	2.42	14.10	4680.00	15870.00	42540.00	37387.20
Min	36*	61.21	9996.00	80.00	50.36	19965.00	0.00	19965.00	8932.00	0.00	28.00	5.60	200.00	15.07	548.00	41.72	292.00	37.70	20.00	5.917	0.00	0.00	1.75	12.00	5600.00	15060.00	41700.00	37680.00
Max	36*	61.39	10161.60	80.00	35.43	17269.00	0.00	17269.00	7842.00	0.00	26.00	5.12	216.00	16.53	540.00	41.10	281.00	36.47	29.00	8.580	0.00	0.00	2.25	9.00	5200.00	16800.00	41760.00	37056.00

Table E.16: Results of the best results of NSF network cases 7, 8 and 9, for 60 seconds.

E.5 GEANT2 best results for 300 seconds.

Symbol	Name
$\#T$	Number of Threads
t_E	Time of Execution
C	Best Cost Solution found
CA	Highest Channel Assigned
t_{sol}	Found Solution Time
$\#i$	Number of Iterations
$\#IS$	Number of Invalid Solutions
$\#G_U$	Number of Greedy Solutions Unfeasible
$\#LS_U$	Number of Local Search Solutions Unfeasible
UD	Unfeasible Degree
$\#IM$	Number of Invert Multiplex used
C_{IM}	Cost % of Invert Multiplex
$\#MX$	Number of Muxponders placed
C_{MX}	Cost % of Muxponders
$\#TX$	Number of Transponders placed
C_{TX}	Cost % of Transponders
$\#3R$	Number of $3R$ regenerators placed
C_{3R}	Cost % of $3R$ regenerators
$\#10$	Number of Multi-Hop Grooming of $10Gb/s$
$\%10$	Traffic % of Multi-Hop Grooming of $10Gb/s$
$\#40$	Number of Multi-hop Grooming of $40Gb/s$
$\%40$	Traffic % of Multi-hop Grooming of $40Gb/s$
$\bar{m}F$	Average Fragmentation at Channel Assigned
MF	Max Fragmentation at Channel Assigned
C_{IM}	Cost of Invert Multiplexers
C_{MX}	Cost of Multiplexers
C_{TX}	Cost of Transponders
C_{3R}	Cost of $3R$ regenerators

Table E.17: Header symbols and their description.

OPERATIONS	COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
	$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
Case 1																												
Mean	1	300.88	7715.92	63.50	155.55	772.90	0.00	0.00	0.00	0.00	14.40	3.73	532.80	37.78	299.60	30.25	198.3	28.24	58.00	5.80	0.00	0.00	12.78	44.90	2880.00	29152.00	23340.00	21787.20
Min	1	300.44	7684.00	64.00	264.47	776.00	0.00	0.00	0.00	0.00	16.00	4.16	542.00	37.98	298.00	30.06	197.0	27.80	61.00	6.10	0.00	0.00	14.15	47.00	3200.00	29180.00	23100.00	21360.00
Max	1	301.16	7733.20	62.00	41.23	766.00	0.00	0.00	0.00	0.00	12.00	3.10	536.00	37.76	302.00	30.65	198.0	28.49	60.00	6.00	0.00	0.00	12.08	44.00	2400.00	29200.00	23700.00	22032.00
Mean	12	301.10	7669.00	63.80	114.80	7977.40	0.00	0.10	0.00	0.00	16.00	4.16	530.20	37.55	298.00	30.00	196.9	27.90	57.00	5.70	0.00	0.00	13.39	44.70	3200.00	28910.00	23100.00	21480.00
Min	12	301.16	7617.20	64.00	37.61	8218.00	0.00	0.00	0.00	0.00	16.00	4.17	528.00	37.55	298.00	30.12	194.0	27.48	64.00	6.40	0.00	0.00	13.65	45.00	3200.00	28800.00	23100.00	21072.00
Max	12	300.88	7690.00	65.00	25.07	8263.00	0.00	0.00	0.00	0.00	16.00	4.15	524.00	37.27	298.00	29.93	199.0	28.30	54.00	5.40	0.00	0.00	13.25	44.00	3200.00	28760.00	23100.00	21840.00
Mean	36	313.07	7674.60	64.20	166.83	8525.90	0.00	0.00	0.00	0.00	14.20	3.68	532.80	37.51	299.80	30.27	196.1	27.95	59.30	5.93	0.00	0.00	13.18	45.90	2840.00	28960.00	23370.00	21576.00
Min	36	313.01	7617.20	64.00	160.27	8199.00	0.00	0.00	0.00	0.00	16.00	4.13	528.00	37.21	298.00	29.84	194.0	27.22	64.00	6.40	0.00	0.00	13.65	45.00	3200.00	28800.00	23100.00	21072.00
Max	36	314.14	7698.00	65.00	149.57	8419.00	0.00	0.00	0.00	0.00	14.00	3.62	542.00	37.73	300.00	30.26	198.0	27.93	64.00	6.40	0.00	0.00	12.81	47.00	2800.00	29180.00	23400.00	21600.00
Mean	36*	303.40	7663.56	64.00	124.64	8256.60	0.00	0.00	0.00	0.00	14.20	3.71	532.80	37.79	299.80	30.50	195.7	28.01	57.50	5.75	0.00	0.00	13.06	45.40	2840.00	28960.00	23370.00	21465.60
Min	36*	301.72	7588.00	63.00	43.13	7984.00	0.00	0.00	0.00	0.00	14.00	3.69	536.00	38.27	300.00	30.84	188.0	27.20	59.00	5.90	0.00	0.00	13.46	46.00	2800.00	29040.00	23400.00	20640.00
Max	36*	301.98	7693.60	66.00	225.65	8229.00	0.00	0.00	0.00	0.00	10.00	2.60	532.00	37.69	304.00	31.19	197.0	28.51	61.00	6.10	0.00	0.00	12.58	47.00	2000.00	29000.00	24000.00	21936.00
Case 2																												
Mean	1	300.75	7986.44	78.30	117.63	800.30	0.00	610.80	0.00	0.00	11.00	2.76	321.60	20.53	559.20	49.11	206.1	27.60	53.30	10.66	0.00	0.00	17.86	61.30	2200.00	16396.00	39222.00	22046.40
Min	1	300.66	7959.20	79.00	280.88	795.00	0.00	597.00	0.00	0.00	10.00	2.51	324.00	20.35	564.00	49.75	203.0	27.38	48.00	9.60	0.00	0.00	19.38	60.00	2000.00	16200.00	39600.00	21792.00
Max	1	300.75	8020.00	78.00	2.46	797.00	0.00	602.00	0.00	0.00	6.00	1.50	322.00	20.55	564.00	49.83	205.0	28.13	57.00	11.40	0.00	0.00	18.35	61.00	1200.00	16480.00	39960.00	22560.00
Mean	12	301.09	7946.96	78.90	123.95	8548.10	0.00	6530.70	0.00	0.00	10.20	2.55	322.40	20.57	559.80	49.21	202.8	27.10	52.30	10.46	0.00	0.00	17.99	60.80	2040.00	16442.00	39330.00	21657.60
Min	12	301.31	7929.20	79.00	185.08	8559.00	0.00	6528.00	0.00	0.00	12.00	2.99	318.00	20.31	558.00	48.74	202.0	26.89	47.00	9.40	0.00	0.00	18.60	63.00	2400.00	16280.00	39060.00	21552.00
Max	12	300.77	7971.20	80.00	188.04	8656.00	0.00	6623.00	0.00	0.00	12.00	3.01	320.00	20.31	558.00	48.91	207.0	27.59	50.00	10.00	0.00	0.00	18.21	58.00	2400.00	16220.00	39060.00	22032.00
Mean	36	312.78	7943.84	78.40	141.13	9056.60	0.00	6910.70	0.00	0.00	9.00	2.24	324.40	21.05	557.20	48.96	198.6	26.76	53.20	10.64	0.00	0.00	17.72	59.60	1800.00	16886.00	39282.00	21470.40
Min	36	314.14	7922.00	76.00	75.29	9034.00	0.00	6941.00	0.00	0.00	8.00	1.99	328.00	20.97	558.00	49.09	200.0	26.60	54.00	10.80	0.00	0.00	16.83	60.00	1600.00	16840.00	39420.00	21360.00
Max	36	307.90	7970.40	79.00	110.98	8973.00	0.00	6865.00	0.00	0.00	12.00	2.98	332.00	21.82	552.00	48.03	198.0	26.09	48.00	9.60	0.00	0.00	19.46	58.00	2400.00	17580.00	38700.00	21024.00
Mean	36*	303.18	7944.52	79.20	163.24	8602.40	0.00	6547.90	0.00	0.00	11.00	2.77	324.20	21.21	555.80	49.11	199.6	26.91	53.10	10.62	0.00	0.00	18.11	60.10	2200.00	16848.00	39018.00	21379.20
Min	36*	301.56	7920.40	80.00	268.98	8489.00	0.00	6462.00	0.00	0.00	10.00	2.53	324.00	20.93	560.00	49.69	199.0	26.85	58.00	11.60	0.00	0.00	18.52	62.00	2000.00	16580.00	39360.00	21264.00
Max	36*	301.98	7970.00	80.00	82.79	8538.00	0.00	6439.00	0.00	0.00	12.00	3.01	322.00	20.88	558.00	49.01	201.0	27.10	54.00	10.80	0.00	0.00	18.54	56.00	2400.00	16640.00	39060.00	21600.00
Case 3																												
Mean	1	300.94	8847.44	79.40	181.17	539.80	0.00	529.60	0.00	0.00	34.20	7.73	276.20	15.63	599.80	50.83	204.9	25.81	55.50	13.88	0.00	0.00	17.11	65.80	6840.00	13826.00	44970.00	22838.40
Min	1	300.81	8792.00	80.00	145.28	535.00	0.00	525.00	0.00	0.00	34.00	7.73	268.00	15.42	600.00	51.18	202.0	25.66	60.00	15.00	0.00	0.00	16.13	62.00	6800.00	13560.00	45000.00	22560.00
Max	1	300.47	8874.00	80.00	173.96	549.00	0.00	536.00	0.00	0.00	36.00	8.11	276.00	15.55	598.00	50.37	207.0	25.96	56.00	14.00	0.00	0.00	17.10	64.00	7200.00	13800.00	44700.00	23040.00
Mean	12	301.54	8809.32	79.30	136.25	8344.90	0.00	8195.30	0.00	0.00	34.00	7.68	273.80	15.47	600.00	50.85	203.2	25.54	55.00	13.75	0.00	0.00	17.76	65.30	6800.00	13690.00	45000.00	22603.20
Min	12	300.88	8781.60	79.00	104.21	8445.00	0.00	8291.00	0.00	0.00	36.00	8.11	270.00	15.20	598.00	50.34	202.0	25.24	57.00	14.25	0.00	0.00	17.13	63.00	7200.00	13500.00	44700.00	22416.00
Max	12	301.42	8829.60	79.00	133.77	8500.00	0.00	8342.00	0.00	0.00	34.00	7.70	272.00	15.39	600.00	50.93	207.0	25.92	49.00	12.25	0.00	0.00	19.15	64.00	6800.00	13600.00	45000.00	22896.00
Mean	36	311.30	8798.08	79.30	143.51	8747.60	0.00	8583.00	0.00	0.00	35.60	8.01	272.00	15.34	598.40	50.37	202.4	25.29	56.20	14.05	0.00	0.00	17.70	64.40	7120.00	13632.00	44760.00	22468.80
Min	36	313.37	8769.20	80.00	289.30	8837.00	0.00	8664.00	0.00	0.00	36.00	8.09	272.00	15.45	598.00	50.20	201.0	24.75	53.00	13.25	0.00	0.00	17.38	62.00	7200.00	13760.00	44700.00	22032.00
Max	36	306.85	8821.60	80.00	67.80	8754.00	0.00	8598.00	0.00	0.00	42.00	9.45	272.00	15.30	592.00	49.27	202.0	25.22	54.00	13.50	0.00	0.00	18.37	71.00	8400.00	13600.00	43800.00	22416.00
Mean	36*	301.96	8812.00	79.10	133.03	8312.80	0.00	8157.10	0.00	0.00	33.60	7.63	273.20	15.50	600.40	51.14	203.4	25.74	56.80	14.20	0.00	0.00	17.34	65.00	6720.00	13660.00	45060.00	22680.00
Min	36*	301.89	8791.20	78.00	127.36	8340.00	0.00	8197.00	0.00	0.00	34.00	7.74	272.00	15.47	600.00	51.19	203.0	25.61	57.00	14.25	0.00	0.00	16.06	63.00	6800.00	13600.00	45000.00	22512.00
Max	36*	302.11	8830.00	79.00	78.70	8380.00	0.00	8231.00	0.00	0.00	38.00	8.61	270.00	15.29	596.00	50.28	206.0	25.82	53.00	13.25	0.00	0.00	17.40	63.00	7600.00	13500.00	44400.00	22800.00

Table E.18: Results of the best results of GEANT2 network cases 1, 2 and 3, for 300 seconds.

OPERATIONS	COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
	$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
Case 4																												
Mean	1	301.32	9628.24	80.00	134.84	217.00	0.00	217.00	0.00	0.00	20.40	4.24	667.60	36.67	340.00	27.32	275.3	31.77	97.20	8.45	0.00	0.00	17.30	56.20	4080.00	35308.00	26304.00	30590.40
Min	1	301.14	9548.00	80.00	69.03	214.00	0.00	214.00	0.00	0.00	20.00	4.19	662.00	36.68	342.00	27.71	272.0	31.42	99.00	8.61	0.00	0.00	16.96	55.00	4000.00	35020.00	26460.00	30000.00
Max	1	300.85	9677.20	80.00	230.02	220.00	0.00	220.00	0.00	0.00	22.00	4.55	660.00	35.98	336.00	26.78	289.0	32.69	92.00	8.00	0.00	0.00	17.79	57.00	4400.00	34820.00	25920.00	31632.00
Mean	12	302.45	9561.40	80.00	193.98	2321.10	0.00	2320.70	0.00	0.00	18.80	3.89	665.40	36.22	343.20	27.57	273.5	31.27	101.60	8.83	0.00	0.00	17.78	56.60	3760.00	34998.00	26640.00	30216.00
Min	12	302.73	9509.60	80.00	280.32	2334.00	0.00	2334.00	0.00	0.00	18.00	3.72	672.00	36.00	344.00	27.62	272.0	30.82	100.00	8.70	0.00	0.00	17.98	57.00	3600.00	34880.00	26760.00	29856.00
Max	12	302.22	9618.00	80.00	89.48	2349.00	0.00	2346.00	0.00	0.00	22.00	4.55	674.00	36.34	340.00	27.05	280.0	31.52	92.00	8.00	0.00	0.00	17.38	58.00	4400.00	35140.00	26160.00	30480.00
Mean	36	314.81	9584.32	80.00	113.19	2443.90	0.00	2443.80	0.00	0.00	19.40	3.98	671.40	36.20	342.60	27.27	271.9	30.98	99.30	8.63	0.00	0.00	17.59	57.70	3880.00	35250.00	26550.00	30163.20
Min	36	313.12	9494.00	80.00	109.84	2449.00	0.00	2449.00	0.00	0.00	20.00	4.12	672.00	36.24	342.00	27.24	266.0	30.15	115.00	10.00	0.00	0.00	17.33	57.00	4000.00	35200.00	26460.00	29280.00
Max	36	313.54	9615.60	80.00	64.91	2438.00	0.00	2438.00	0.00	0.00	20.00	4.07	664.00	35.27	342.00	26.95	280.0	31.63	88.00	7.65	0.00	0.00	18.48	58.00	4000.00	34640.00	26460.00	31056.00
Mean	36*	303.92	9560.08	80.00	125.22	2355.70	0.00	2355.50	0.00	0.00	21.60	4.52	666.60	36.69	340.00	27.40	273.1	31.39	100.00	8.70	0.00	0.00	17.89	57.00	4320.00	35080.00	26196.00	30004.80
Min	36*	303.69	9494.00	80.00	189.82	2369.00	0.00	2369.00	0.00	0.00	20.00	4.21	672.00	37.08	342.00	27.87	266.0	30.84	115.00	10.00	0.00	0.00	17.33	57.00	4000.00	35200.00	26460.00	29280.00
Max	36*	303.54	9595.20	80.00	67.13	2358.00	0.00	2358.00	0.00	0.00	24.00	5.00	670.00	37.08	338.00	26.95	272.0	30.97	91.00	7.91	0.00	0.00	17.92	57.00	4800.00	35580.00	25860.00	29712.00
Case 5																												
Mean	1	301.03	9295.60	79.00	148.51	336.10	0.00	335.00	0.00	0.00	28.00	6.02	398.40	21.52	634.00	46.54	227.0	25.92	93.80	16.31	0.00	0.00	15.62	56.50	5600.00	20000.00	43260.00	24096.00
Min	1	300.53	9256.80	79.00	184.38	335.00	0.00	333.00	0.00	0.00	30.00	6.48	396.00	21.39	632.00	46.41	227.0	25.72	101.00	17.57	0.00	0.00	16.29	55.00	6000.00	19800.00	42960.00	23808.00
Max	1	300.75	9344.80	79.00	227.67	335.00	0.00	335.00	0.00	0.00	30.00	6.42	396.00	21.36	632.00	45.97	233.0	26.25	93.00	16.17	0.00	0.00	16.29	58.00	6000.00	19960.00	42960.00	24528.00
Mean	12	301.71	9258.48	79.10	141.93	3587.50	0.00	3571.20	0.00	0.00	29.20	6.27	396.80	21.37	632.00	46.21	224.5	25.57	88.90	15.46	0.00	0.00	15.89	54.80	5840.00	19900.00	43032.00	23812.80
Min	12	301.67	9228.80	80.00	12.79	3558.00	0.00	3540.00	0.00	0.00	28.00	5.99	402.00	21.51	634.00	46.29	219.0	24.96	93.00	16.17	0.00	0.00	15.58	60.00	5600.00	20100.00	43260.00	23328.00
Max	12	301.66	9294.40	78.00	107.27	3610.00	0.00	3594.00	0.00	0.00	30.00	6.44	402.00	21.82	628.00	45.88	225.0	25.67	85.00	14.78	0.00	0.00	16.08	46.00	6000.00	20320.00	42720.00	23904.00
Mean	36	311.53	9250.56	78.10	135.38	3697.50	0.00	3682.40	0.00	0.00	28.40	6.08	398.60	21.40	633.20	46.19	222.2	25.30	95.40	16.59	0.00	0.00	16.01	55.60	5680.00	20000.00	43176.00	23649.60
Min	36	310.21	9220.80	79.00	23.59	3713.00	0.00	3700.00	0.00	0.00	22.00	4.69	392.00	20.91	640.00	47.12	219.0	25.66	88.00	15.30	0.00	0.00	16.52	58.00	4400.00	19600.00	44160.00	24048.00
Max	36	312.87	9279.20	78.00	236.45	3700.00	0.00	3687.00	0.00	0.00	32.00	6.84	402.00	21.65	630.00	45.59	222.0	25.08	95.00	16.52	0.00	0.00	16.21	61.00	6400.00	20260.00	42660.00	23472.00
Mean	36*	305.12	9262.80	79.10	184.82	3551.00	0.00	3535.60	0.00	0.00	29.20	6.30	395.60	21.41	632.80	46.51	225.5	25.78	91.10	15.84	0.00	0.00	16.06	56.50	5840.00	19828.00	43080.00	23880.00
Min	36*	303.26	9240.80	78.00	299.72	3425.00	0.00	3410.00	0.00	0.00	30.00	6.49	388.00	20.99	632.00	46.49	225.0	26.02	90.00	15.65	0.00	0.00	15.19	57.00	6000.00	19400.00	42960.00	24048.00
Max	36*	302.91	9297.20	79.00	51.23	3614.00	0.00	3600.00	0.00	0.00	30.00	6.45	406.00	21.83	632.00	46.21	226.0	25.50	88.00	15.30	0.00	0.00	17.27	56.00	6000.00	20300.00	42960.00	23712.00
Case 6																												
Mean	1	301.19	10240.76	79.90	97.08	321.00	0.00	320.60	0.00	0.00	36.00	7.03	338.20	16.82	691.20	51.04	227.2	25.11	89.90	19.54	0.00	0.00	18.46	64.10	7200.00	17222.00	52272.00	25713.60
Min	1	300.71	10189.60	80.00	4.59	323.00	0.00	323.00	0.00	0.00	30.00	5.89	340.00	17.06	698.00	52.23	217.0	24.83	95.00	20.65	0.00	0.00	17.75	55.00	6000.00	17380.00	53220.00	25296.00
Max	1	300.83	10263.60	80.00	110.32	323.00	0.00	323.00	0.00	0.00	36.00	7.02	344.00	17.13	692.00	50.98	224.0	24.88	97.00	21.09	0.00	0.00	17.79	63.00	7200.00	17580.00	52320.00	25536.00
Mean	12	301.75	10180.40	79.30	132.31	3344.40	0.00	3339.30	0.00	0.00	36.60	7.15	334.60	16.59	691.40	51.03	223.2	24.69	88.70	19.28	0.00	0.00	18.66	61.20	7320.00	16982.00	52230.00	25272.00
Min	12	301.94	10142.40	78.00	262.30	3365.00	0.00	3359.00	0.00	0.00	36.00	7.10	336.00	16.56	696.00	51.82	220.0	24.51	89.00	19.35	0.00	0.00	19.71	65.00	7200.00	16800.00	52560.00	24864.00
Max	12	301.30	10209.20	80.00	12.50	3385.00	0.00	3379.00	0.00	0.00	40.00	7.84	340.00	16.87	688.00	50.66	223.0	24.64	90.00	19.57	0.00	0.00	18.02	60.00	8000.00	17220.00	51720.00	25152.00
Mean	36	313.02	10181.60	79.60	122.15	3515.80	0.00	3509.10	0.00	0.00	35.60	6.91	335.00	16.50	692.80	50.86	223.3	24.55	92.50	20.11	0.00	0.00	19.00	62.20	7120.00	16996.00	52404.00	25296.00
Min	36	313.64	10154.80	79.00	154.44	3520.00	0.00	3513.00	0.00	0.00	28.00	5.44	326.00	15.98	704.00	52.18	223.0	24.97	91.00	19.78	0.00	0.00	19.85	62.00	5600.00	16460.00	53760.00	25728.00
Max	36	313.89	10206.80	80.00	293.50	3528.00	0.00	3517.00	0.00	0.00	40.00	7.75	338.00	16.79	684.00	49.85	224.0	24.45	90.00	19.57	0.00	0.00	18.71	65.00	8000.00	17340.00	51480.00	25248.00
Mean	36*	303.06	10188.84	79.80	142.36	3408.40	0.00	3403.10	0.00	0.00	36.20	7.11	335.40	16.61	693.80	51.44	224.8	24.84	87.90	19.11	0.00	0.00	18.34	62.70	7240.00	16928.00	52410.00	25310.40
Min	36*	303.40	10156.80	80.00	187.29	3395.00	0.00	3391.00	0.00	0.00	38.00	7.48	326.00	16.21	694.00	51.45	227.0	24.86	88.00	19.13	0.00	0.00	18.44	64.00	7600.00	16460.00	52260.00	25248.00
Max	36*	302.84	10230.80	80.00	218.56	3350.00	0.00	3344.00	0.00	0.00	36.00	7.04	338.00	16.68	696.00	51.37	225.0	24.91	89.00	19.35	0.00	0.00	20.06	67.00	7200.00	17060.00	52560.00	25488.00

Table E.19: Results of the best results of GEANT2 network cases 4, 5 and 6, for 300 seconds.

OPERATIONS	COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
	$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
Case 7																												
Mean	1	301.77	10578.68	79.90	168.93	152.30	0.00	152.10	0.00	0.00	15.20	2.87	786.20	38.41	394.00	29.56	285.3	29.16	120.30	9.09	0.00	0.00	15.04	55.20	3040.00	40630.00	31272.00	30844.80
Min	1	302.02	10474.40	80.00	224.39	152.00	0.00	152.00	0.00	0.00	16.00	3.06	792.00	38.84	390.00	29.56	277.0	28.55	104.00	7.86	0.00	0.00	16.13	56.00	3200.00	40680.00	30960.00	29904.00
Max	1	300.99	10661.20	80.00	184.72	151.00	0.00	151.00	0.00	0.00	16.00	3.00	794.00	37.84	398.00	29.49	301.0	29.67	117.00	8.84	0.00	0.00	14.04	54.00	3200.00	40340.00	31440.00	31632.00
Mean	12	303.30	10512.72	79.80	104.00	1576.00	0.00	1573.70	0.00	0.00	15.80	2.98	780.80	38.28	393.00	29.39	280.6	28.52	121.00	9.15	0.00	0.00	15.38	55.20	3160.00	40574.00	31158.00	30235.20
Min	12	303.64	10447.60	79.00	211.41	1580.00	0.00	1578.00	0.00	0.00	18.00	3.40	776.00	38.57	388.00	28.96	273.0	27.74	107.00	8.09	0.00	0.00	15.79	56.00	3600.00	40840.00	30660.00	29376.00
Max	12	303.11	10558.00	80.00	2.98	1576.00	0.00	1575.00	0.00	0.00	16.00	3.02	778.00	38.59	390.00	29.18	280.0	28.73	136.00	10.28	0.00	0.00	16.19	57.00	3200.00	40940.00	30960.00	30480.00
Mean	36	314.54	10517.88	80.00	171.98	1629.90	0.00	1628.10	0.00	0.00	17.40	3.26	782.20	38.02	392.20	29.04	282.3	28.32	117.60	8.89	0.00	0.00	15.65	54.70	3480.00	40536.00	30966.00	30196.80
Min	36	309.99	10496.00	80.00	80.04	1616.00	0.00	1616.00	0.00	0.00	16.00	3.02	780.00	38.26	390.00	29.21	279.0	28.53	105.00	7.94	0.00	0.00	16.15	56.00	3200.00	40560.00	30960.00	30240.00
Max	36	315.31	10552.80	80.00	45.33	1621.00	0.00	1620.00	0.00	0.00	16.00	3.03	780.00	37.96	398.00	29.75	286.0	29.11	109.00	8.24	0.00	0.00	16.38	55.00	3200.00	40120.00	31440.00	30768.00
Mean	36*	305.73	10509.68	79.70	168.30	1570.20	0.00	1568.40	0.00	0.00	16.60	3.16	783.80	38.69	391.00	29.46	280.9	28.69	117.80	8.90	0.00	0.00	15.34	55.50	3320.00	40662.00	30966.00	30148.80
Min	36*	306.41	10447.60	79.00	216.56	1572.00	0.00	1571.00	0.00	0.00	18.00	3.45	776.00	39.09	388.00	29.35	273.0	28.12	107.00	8.09	0.00	0.00	15.79	56.00	3600.00	40840.00	30660.00	29376.00
Max	36*	304.89	10544.40	78.00	301.99	1554.00	0.00	1553.00	0.00	0.00	14.00	2.66	792.00	38.88	392.00	29.65	279.0	28.82	132.00	9.98	0.00	0.00	14.69	49.00	2800.00	41000.00	31260.00	30384.00
Case 8																												
Mean	1	301.85	11019.04	80.00	147.86	136.90	0.00	136.90	0.00	0.00	35.00	6.35	473.20	21.71	725.40	44.81	286.2	27.13	125.20	18.91	0.00	0.00	17.13	56.40	7000.00	23922.00	49374.00	29894.40
Min	1	302.80	10984.40	80.00	108.65	140.00	0.00	140.00	0.00	0.00	32.00	5.83	470.00	21.39	732.00	45.56	286.0	27.22	121.00	18.28	0.00	0.00	14.81	52.00	6400.00	23500.00	50040.00	29904.00
Max	1	301.06	11048.00	80.00	8.21	134.00	0.00	134.00	0.00	0.00	32.00	5.79	476.00	21.54	732.00	45.29	285.0	27.37	122.00	18.43	0.00	0.00	17.46	56.00	6400.00	23800.00	50040.00	30240.00
Mean	12	303.40	10961.12	79.30	132.38	1356.50	0.00	1356.40	0.00	0.00	34.40	6.24	469.40	21.50	726.80	44.91	283.3	26.77	125.10	18.90	0.00	0.00	16.27	55.30	6880.00	23704.00	49512.00	29515.20
Min	12	303.67	10844.80	79.00	222.83	1357.00	0.00	1357.00	0.00	0.00	36.00	6.55	464.00	21.10	728.00	44.96	274.0	26.01	119.00	17.98	0.00	0.00	17.08	56.00	7200.00	23200.00	49440.00	28608.00
Max	12	303.42	11003.20	80.00	118.79	1364.00	0.00	1364.00	0.00	0.00	34.00	6.15	478.00	22.16	722.00	44.55	283.0	26.66	131.00	19.79	0.00	0.00	16.83	62.00	6800.00	24500.00	49260.00	29472.00
Mean	36	314.93	10960.96	79.60	141.15	1399.20	0.00	1399.10	0.00	0.00	36.00	6.50	470.00	21.54	723.40	44.39	282.1	26.53	125.00	18.88	0.00	0.00	16.43	52.90	7200.00	23860.00	49164.00	29385.60
Min	36	313.75	10924.80	80.00	163.05	1406.00	0.00	1406.00	0.00	0.00	36.00	6.50	450.00	20.79	724.00	44.39	288.0	26.89	119.00	17.98	0.00	0.00	16.19	49.00	7200.00	23040.00	49200.00	29808.00
Max	36	319.71	11005.60	80.00	3.15	1438.00	0.00	1438.00	0.00	0.00	36.00	6.49	482.00	22.30	716.00	43.89	282.0	26.46	122.00	18.43	0.00	0.00	16.42	50.00	7200.00	24760.00	48720.00	29376.00
Mean	36*	306.20	10944.00	79.90	152.22	1358.10	0.00	1358.10	0.00	0.00	35.00	6.40	469.00	21.76	724.20	45.05	281.2	26.80	125.40	18.94	0.00	0.00	16.88	56.60	7000.00	23810.00	49302.00	29328.00
Min	36*	306.17	10844.80	79.00	223.38	1349.00	0.00	1349.00	0.00	0.00	36.00	6.64	464.00	21.39	728.00	45.59	274.0	26.38	119.00	17.98	0.00	0.00	17.08	56.00	7200.00	23200.00	49440.00	28608.00
Max	36*	305.39	11006.80	80.00	16.35	1362.00	0.00	1362.00	0.00	0.00	34.00	6.18	476.00	21.77	730.00	45.19	284.0	26.86	127.00	19.18	0.00	0.00	16.35	55.00	6800.00	23960.00	49740.00	29568.00
Case 9																												
Mean	1	301.65	12660.96	80.00	149.59	160.30	0.00	160.30	0.00	0.00	46.20	7.30	401.60	16.34	788.60	46.88	334.4	29.48	117.80	22.27	0.00	0.00	14.62	53.00	9240.00	20682.00	59358.00	37329.60
Min	1	301.75	12562.00	80.00	173.43	159.00	0.00	159.00	0.00	0.00	46.00	7.32	408.00	17.07	782.00	46.95	321.0	28.66	118.00	22.31	0.00	0.00	14.69	54.00	9200.00	21440.00	58980.00	36000.00
Max	1	300.78	12740.00	80.00	251.63	166.00	0.00	166.00	0.00	0.00	48.00	7.54	400.00	15.70	796.00	46.81	348.0	29.95	116.00	21.93	0.00	0.00	16.08	56.00	9600.00	20000.00	59640.00	38160.00
Mean	12	303.10	12584.96	80.00	156.72	1552.80	0.00	1552.80	0.40	0.00	47.00	7.40	398.80	16.23	787.00	46.62	328.3	28.87	114.80	21.70	0.00	0.00	14.92	54.80	9400.00	20602.00	59190.00	36657.60
Min	12	303.39	12503.20	80.00	199.46	1561.00	0.00	1561.00	0.00	0.00	46.00	7.25	400.00	16.27	786.00	46.64	319.0	28.32	119.00	22.50	0.00	0.00	15.31	52.00	9200.00	20660.00	59220.00	35952.00
Max	12	303.67	12649.60	80.00	153.85	1572.00	0.00	1572.00	0.00	0.00	48.00	7.58	406.00	16.32	792.00	46.88	331.0	29.05	116.00	21.93	0.00	0.00	14.37	55.00	9600.00	20680.00	59400.00	36816.00
Mean	36	314.66	12558.88	80.00	159.68	1621.30	0.00	1621.30	0.40	0.00	47.40	7.42	398.80	16.13	787.40	46.34	325.9	28.46	115.00	21.74	0.00	0.00	14.75	52.80	9480.00	20590.00	59178.00	36340.80
Min	36	316.29	12459.60	80.00	58.52	1628.00	0.00	1628.00	2.00	0.00	48.00	7.70	398.00	16.81	780.00	47.10	316.0	28.39	113.00	21.36	0.00	0.00	15.02	57.00	9600.00	20940.00	58680.00	35376.00
Max	36	312.86	12632.00	80.00	150.93	1602.00	0.00	1602.00	0.00	0.00	48.00	7.53	398.00	15.79	792.00	46.61	335.0	29.19	112.00	21.17	0.00	0.00	14.79	57.00	9600.00	20120.00	59400.00	37200.00
Mean	36*	305.85	12578.92	80.00	178.23	1564.90	0.00	1564.90	0.10	0.00	48.00	7.63	401.20	16.42	787.60	47.01	327.0	28.94	115.90	21.91	0.00	0.00	14.71	54.70	9600.00	20650.00	59136.00	36403.20
Min	36*	306.23	12503.20	80.00	201.18	1549.00	0.00	1549.00	0.00	0.00	46.00	7.36	400.00	16.52	786.00	47.36	319.0	28.75	119.00	22.50	0.00	0.00	15.31	52.00	9200.00	20660.00	59220.00	35952.00
Max	36*	308.35	12627.60	80.00	300.74	1542.00	0.00	1542.00	0.00	0.00	48.00	7.60	406.00	16.77	780.00	46.47	331.0	29.16	115.00	21.74	0.00	0.00	14.94	60.00	9600.00	21180.00	58680.00	36816.00

Table E.20: Results of the best results of GEANT2 network cases 7, 8 and 9, for 300 seconds.

E.6 EON best results for 300 seconds.

Symbol	Name
$\#T$	Number of Threads
t_E	Time of Execution
C	Best Cost Solution found
CA	Highest Channel Assigned
t_{sol}	Found Solution Time
$\#i$	Number of Iterations
$\#IS$	Number of Invalid Solutions
$\#G_U$	Number of Greedy Solutions Unfeasible
$\#LS_U$	Number of Local Search Solutions Unfeasible
UD	Unfeasible Degree
$\#IM$	Number of Invert Multiplex used
C_{IM}	Cost % of Invert Multiplex
$\#MX$	Number of Muxponders placed
C_{MX}	Cost % of Muxponders
$\#TX$	Number of Transponders placed
C_{TX}	Cost % of Transponders
$\#3R$	Number of $3R$ regenerators placed
C_{3R}	Cost % of $3R$ regenerators
#10	Number of Multi-Hop Grooming of $10Gb/s$
%10	Traffic % of Multi-Hop Grooming of $10Gb/s$
#40	Number of Multi-hop Grooming of $40Gb/s$
%40	Traffic % of Multi-hop Grooming of $40Gb/s$
$\bar{m}F$	Average Fragmentation at Channel Assigned
MF	Max Fragmentation at Channel Assigned
C_{IM}	Cost of Invert Multiplexers
C_{MX}	Cost of Multiplexers
C_{TX}	Cost of Transponders
C_{3R}	Cost of $3R$ regenerators

Table E.21: Header symbols and their description.

OPERATIONS	COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
	$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
Case 1																												
Mean	1	300.32	6964.92	59.30	93.71	12153.90	0.00	0.00	0.00	0.00	18.60	5.34	511.60	38.15	300.80	33.85	139.1	22.67	19.00	1.90	0.00	0.00	5.22	29.70	3720.00	26568.00	23574.00	15787.20
Min	1	300.38	6947.60	58.00	201.51	12145.00	0.00	0.00	0.00	0.00	20.00	5.76	518.00	37.97	300.00	33.68	141.0	22.59	19.00	1.90	0.00	0.00	6.51	31.00	4000.00	26380.00	23400.00	15696.00
Max	1	300.22	6976.40	60.00	64.12	12099.00	0.00	0.00	0.00	0.00	18.00	5.16	504.00	37.96	302.00	33.97	138.0	22.91	23.00	2.30	0.00	0.00	4.92	30.00	3600.00	26480.00	23700.00	15984.00
Mean	12	300.33	6929.92	60.00	97.50	119753.20	0.00	0.00	0.00	0.00	18.60	5.34	511.80	38.09	301.40	33.91	135.3	22.19	20.50	2.05	0.00	0.00	5.58	28.00	3720.00	26518.00	23610.00	15451.20
Min	12	300.27	6912.80	59.00	14.31	122937.00	0.00	0.00	0.00	0.00	20.00	5.74	512.00	38.11	300.00	33.58	134.0	21.76	19.00	1.90	0.00	0.00	6.05	31.00	4000.00	26560.00	23400.00	15168.00
Max	12	300.25	6948.40	63.00	10.48	123855.00	0.00	0.00	0.00	0.00	16.00	4.59	518.00	38.06	304.00	34.42	137.0	22.58	26.00	2.60	0.00	0.00	5.43	30.00	3200.00	26540.00	24000.00	15744.00
Mean	36	311.99	6929.84	57.70	106.44	131454.70	0.00	0.00	0.00	0.00	18.20	5.22	507.00	37.94	301.80	33.92	135.7	22.24	18.40	1.84	0.00	0.00	5.13	29.50	3640.00	26470.00	23670.00	15518.40
Min	36	309.55	6912.80	59.00	30.89	131761.00	0.00	0.00	0.00	0.00	20.00	5.75	512.00	38.17	300.00	33.62	134.0	21.80	19.00	1.90	0.00	0.00	6.05	31.00	4000.00	26560.00	23400.00	15168.00
Max	36	305.76	6949.20	57.00	96.13	129824.00	0.00	0.00	0.00	0.00	20.00	5.73	502.00	38.04	300.00	33.54	138.0	22.29	22.00	2.20	0.00	0.00	5.22	29.00	4000.00	26540.00	23400.00	15552.00
Mean	36*	304.31	6934.80	59.30	138.38	127670.20	0.00	0.00	0.00	0.00	18.20	5.25	507.80	38.30	301.80	34.13	134.4	22.32	21.10	2.11	0.00	0.00	5.14	28.80	3640.00	26558.00	23670.00	15480.00
Min	36*	301.25	6914.40	55.00	206.34	126143.00	0.00	0.00	0.00	0.00	18.00	5.21	506.00	38.44	302.00	34.28	135.0	22.08	19.00	1.90	0.00	0.00	4.92	32.00	3600.00	26580.00	23700.00	15264.00
Max	36*	301.25	6948.40	62.00	251.39	126490.00	0.00	0.00	0.00	0.00	18.00	5.18	508.00	38.40	302.00	34.11	133.0	22.31	25.00	2.50	0.00	0.00	5.46	30.00	3600.00	26680.00	23700.00	15504.00
Case 2																												
Mean	1	300.32	8042.24	59.40	133.22	13711.80	0.00	0.00	0.00	0.00	23.40	5.82	251.40	17.98	551.00	49.68	192.9	26.52	20.40	4.08	0.00	0.00	6.41	24.50	4680.00	14462.00	39954.00	21326.40
Min	1	300.24	8021.20	55.00	255.64	13747.00	0.00	0.00	0.00	0.00	24.00	5.98	254.00	17.63	556.00	50.12	194.0	26.27	31.00	6.20	0.00	0.00	7.62	25.00	4800.00	14140.00	40200.00	21072.00
Max	1	300.22	8067.20	64.00	214.14	13688.00	0.00	0.00	0.00	0.00	24.00	5.95	252.00	17.21	556.00	49.83	197.0	27.01	18.00	3.60	0.00	0.00	6.54	29.00	4800.00	13880.00	40200.00	21792.00
Mean	12	300.34	8013.92	55.30	157.97	120593.10	0.00	0.70	0.00	0.00	22.40	5.57	249.20	17.71	553.60	49.97	191.1	26.37	16.90	3.38	0.00	0.00	5.96	23.60	4480.00	14248.00	40200.00	21211.20
Min	12	300.27	7993.20	58.00	276.23	120499.00	0.00	1.00	0.00	0.00	22.00	5.45	244.00	17.30	558.00	50.19	191.0	26.12	18.00	3.60	0.00	0.00	5.59	25.00	4400.00	13960.00	40500.00	21072.00
Max	12	300.44	8034.40	58.00	229.43	122247.00	0.00	0.00	0.00	0.00	22.00	5.47	246.00	18.24	550.00	49.78	190.0	26.45	16.00	3.20	0.00	0.00	6.27	23.00	4400.00	14660.00	40020.00	21264.00
Mean	36	312.99	8014.52	56.30	156.53	132907.50	0.00	1.20	0.00	0.00	23.60	5.85	247.80	17.45	554.00	49.73	191.8	26.33	17.90	3.58	0.00	0.00	6.03	24.90	4720.00	14074.00	40116.00	21235.20
Min	36	308.80	7993.20	65.00	188.04	132328.00	0.00	2.00	0.00	0.00	22.00	5.43	248.00	17.83	550.00	49.41	188.0	26.02	17.00	3.40	0.00	0.00	5.22	22.00	4400.00	14440.00	40020.00	21072.00
Max	36	313.92	8028.40	63.00	160.37	135656.00	0.00	2.00	0.00	0.00	22.00	5.44	252.00	17.17	558.00	50.10	197.0	26.60	17.00	3.40	0.00	0.00	6.59	27.00	4400.00	13880.00	40500.00	21504.00
Mean	36*	302.90	8014.92	59.70	191.43	129001.80	0.00	0.80	0.00	0.00	22.40	5.59	249.80	17.70	554.40	50.22	191.5	26.49	19.30	3.86	0.00	0.00	6.32	25.70	4480.00	14186.00	40248.00	21235.20
Min	36*	301.19	7980.80	67.00	261.18	128735.00	0.00	1.00	0.00	0.00	22.00	5.51	246.00	17.22	558.00	50.75	192.0	26.52	17.00	3.40	0.00	0.00	5.81	25.00	4400.00	13740.00	40500.00	21168.00
Max	36*	301.19	8041.20	57.00	84.63	130966.00	0.00	1.00	0.00	0.00	22.00	5.47	264.00	17.96	550.00	49.77	196.0	26.80	25.00	5.00	0.00	0.00	7.03	23.00	4400.00	14440.00	40020.00	21552.00
Case 3																												
Mean	1	300.32	8024.32	52.10	186.47	16678.00	0.00	0.00	0.00	0.00	15.80	3.94	186.00	12.76	642.20	64.19	121.3	19.11	18.40	5.26	0.00	0.00	4.30	35.20	3160.00	10242.00	51510.00	15331.20
Min	1	300.44	7970.80	51.00	204.25	16675.00	0.00	0.00	0.00	0.00	22.00	5.52	184.00	12.75	638.00	63.61	116.0	18.13	13.00	3.71	0.00	0.00	4.78	37.00	4400.00	10160.00	50700.00	14448.00
Max	1	300.22	8044.80	56.00	278.80	16653.00	0.00	0.00	0.00	0.00	16.00	3.98	184.00	12.43	644.00	64.14	124.0	19.45	20.00	5.71	0.00	0.00	3.78	38.00	3200.00	10000.00	51600.00	15648.00
Mean	12	300.48	7996.80	52.00	209.81	168726.40	0.00	0.00	0.00	0.00	17.00	4.23	185.80	12.74	640.60	63.87	120.8	18.70	17.90	5.11	0.00	0.00	4.58	30.10	3400.00	10238.00	51306.00	15024.00
Min	12	301.28	7978.40	52.00	109.26	163173.00	0.00	0.00	0.00	0.00	16.00	3.98	188.00	12.70	644.00	64.25	115.0	18.41	16.00	4.57	0.00	0.00	5.22	36.00	3200.00	10200.00	51600.00	14784.00
Max	12	300.24	8014.00	51.00	252.60	169750.00	0.00	0.00	0.00	0.00	18.00	4.48	184.00	13.18	634.00	63.20	123.0	18.80	17.00	4.86	0.00	0.00	3.78	26.00	3600.00	10600.00	50820.00	15120.00
Mean	36	312.18	8000.60	51.10	144.53	182912.70	0.00	0.00	0.00	0.00	15.40	3.83	183.60	12.48	644.60	64.23	119.7	18.88	18.80	5.37	0.00	0.00	4.33	32.70	3080.00	10044.00	51690.00	15192.00
Min	36	314.61	7977.20	50.00	116.11	184693.00	0.00	0.00	0.00	0.00	12.00	2.98	186.00	12.55	648.00	64.86	118.0	18.73	20.00	5.71	0.00	0.00	3.95	36.00	2400.00	10100.00	52200.00	15072.00
Max	36	308.07	8014.80	51.00	247.20	181487.00	0.00	0.00	0.00	0.00	12.00	2.99	182.00	12.34	648.00	65.05	124.0	19.50	16.00	4.57	0.00	0.00	4.81	37.00	2400.00	9900.00	52200.00	15648.00
Mean	36*	301.10	8004.84	50.50	191.13	174337.10	0.00	0.00	0.00	0.00	15.20	3.80	184.20	12.57	644.80	64.61	119.8	19.03	17.40	4.97	0.00	0.00	4.15	30.40	3040.00	10058.00	51720.00	15230.40
Min	36*	301.02	7984.00	52.00	294.53	174978.00	0.00	0.00	0.00	0.00	12.00	3.01	188.00	12.98	648.00	65.38	116.0	18.64	18.00	5.14	0.00	0.00	5.46	41.00	2400.00	10360.00	52200.00	14880.00
Max	36*	301.08	8021.60	51.00	282.24	178896.00	0.00	0.00	0.00	0.00	16.00	3.99	180.00	12.42	644.00	64.33	119.0	19.27	20.00	5.71	0.00	0.00	4.22	39.00	3200.00	9960.00	51600.00	15456.00

Table E.22: Results of the best results of EON network cases 1, 2 and 3, for 300 seconds.

OPERATIONS	COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
	$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
Case 4																												
Mean	1	300.46	8654.24	65.70	149.28	5975.70	0.00	14.90	0.00	0.00	21.40	4.95	639.40	38.40	378.60	34.42	173.4	22.23	35.30	2.82	0.00	0.00	7.00	33.50	4280.00	33234.00	29790.00	19238.40
Min	1	300.32	8616.40	65.00	0.80	5963.00	0.00	15.00	0.00	0.00	22.00	5.11	632.00	38.53	378.00	34.47	171.0	21.89	35.00	2.80	0.00	0.00	6.46	31.00	4400.00	33200.00	29700.00	18864.00
Max	1	300.33	8671.20	65.00	177.92	6013.00	0.00	17.00	0.00	0.00	20.00	4.61	644.00	38.43	380.00	34.60	172.0	22.36	35.00	2.80	0.00	0.00	7.22	39.00	4000.00	33320.00	30000.00	19392.00
Mean	12	300.47	8622.44	64.90	127.45	60132.40	0.00	148.10	0.00	0.00	21.60	4.99	637.80	38.25	378.40	34.36	169.5	21.96	32.20	2.58	0.00	0.00	7.27	34.70	4320.00	33122.00	29760.00	19022.40
Min	12	300.36	8595.60	64.00	134.78	61400.00	0.00	134.00	0.00	0.00	22.00	5.07	632.00	38.10	378.00	34.25	166.0	21.70	31.00	2.48	0.00	0.00	6.76	29.00	4400.00	33040.00	29700.00	18816.00
Max	12	300.33	8646.40	64.00	130.29	57550.00	0.00	157.00	0.00	0.00	22.00	5.08	638.00	38.12	378.00	34.29	176.0	22.33	32.00	2.56	0.00	0.00	6.03	27.00	4400.00	33020.00	29700.00	19344.00
Mean	36	311.58	8620.56	65.50	129.68	65724.50	0.00	152.70	0.00	0.00	21.00	4.85	640.20	38.36	379.00	34.48	169.9	21.89	32.40	2.59	0.00	0.00	7.74	34.80	4200.00	33210.00	29850.00	18945.60
Min	36	307.12	8557.20	62.00	113.44	65340.00	0.00	159.00	0.00	0.00	20.00	4.67	634.00	38.73	380.00	35.06	165.0	21.54	30.00	2.40	0.00	0.00	8.03	34.00	4000.00	33140.00	30000.00	18432.00
Max	36	306.07	8645.20	70.00	145.28	64945.00	0.00	169.00	0.00	0.00	20.00	4.60	650.00	38.30	380.00	34.51	174.0	22.03	27.00	2.16	0.00	0.00	8.86	40.00	4000.00	33300.00	30000.00	19152.00
Mean	36*	302.84	8626.12	64.20	186.76	63105.70	0.00	150.60	0.00	0.00	21.20	4.92	636.60	38.51	378.80	34.57	168.6	22.00	33.60	2.69	0.00	0.00	7.26	37.20	4240.00	33222.00	29820.00	18979.20
Min	36*	301.33	8613.20	65.00	198.81	64241.00	0.00	134.00	0.00	0.00	20.00	4.64	634.00	38.29	380.00	34.83	168.0	22.24	29.00	2.32	0.00	0.00	7.08	39.00	4000.00	32980.00	30000.00	19152.00
Max	36*	301.13	8652.40	61.00	288.51	62647.00	0.00	140.00	0.00	0.00	20.00	4.62	630.00	38.63	380.00	34.67	169.0	22.08	45.00	3.60	0.00	0.00	7.32	33.00	4000.00	33420.00	30000.00	19104.00
Case 5																												
Mean	1	300.42	9791.48	79.70	172.98	4473.20	0.00	4473.10	189.20	0.00	24.20	4.94	328.80	21.39	663.80	50.03	189.6	23.63	34.20	5.47	0.00	0.00	9.22	36.00	4840.00	20944.00	48990.00	23140.80
Min	1	300.52	9780.00	79.00	199.65	4624.00	0.00	4624.00	203.00	0.00	24.00	4.91	320.00	21.17	668.00	50.37	189.0	23.56	40.00	6.40	0.00	0.00	7.81	31.00	4800.00	20700.00	49260.00	23040.00
Max	1	300.32	9812.80	79.00	238.71	4579.00	0.00	4579.00	175.00	0.00	26.00	5.30	334.00	21.77	658.00	49.40	188.0	23.53	29.00	4.64	0.00	0.00	9.24	41.00	5200.00	21360.00	48480.00	23088.00
Mean	12	300.47	9755.32	79.70	174.13	47115.20	0.00	47114.80	2002.70	0.00	23.80	4.86	329.20	21.31	664.20	50.12	188.2	23.39	34.70	5.55	0.00	0.00	9.11	33.20	4760.00	20852.00	49050.00	22891.20
Min	12	300.39	9719.60	79.00	64.94	46812.00	0.00	46812.00	1987.00	0.00	22.00	4.50	328.00	21.52	662.00	50.15	188.0	23.15	36.00	5.76	0.00	0.00	9.24	32.00	4400.00	21060.00	49080.00	22656.00
Max	12	300.38	9776.80	80.00	165.55	48355.00	0.00	48354.00	2080.00	0.00	20.00	4.09	344.00	21.53	664.00	50.48	189.0	23.85	32.00	5.12	0.00	0.00	7.86	28.00	4000.00	21060.00	49380.00	23328.00
Mean	36	312.26	9738.24	79.40	129.78	51392.20	0.00	51392.00	2172.30	0.00	22.80	4.65	330.40	21.39	665.20	50.17	185.8	23.09	35.10	5.62	0.00	0.00	9.72	35.80	4560.00	20976.00	49200.00	22646.40
Min	36	317.29	9676.40	80.00	190.91	52042.00	0.00	52041.00	2169.00	0.00	24.00	4.92	330.00	21.23	668.00	50.48	184.0	22.53	34.00	5.44	0.00	0.00	10.16	36.00	4800.00	20720.00	49260.00	21984.00
Max	36	308.22	9771.60	78.00	18.36	51030.00	0.00	51030.00	2175.00	0.00	24.00	4.89	334.00	21.65	668.00	50.21	184.0	22.85	39.00	6.24	0.00	0.00	9.16	36.00	4800.00	21240.00	49260.00	22416.00
Mean	36*	302.81	9742.44	79.60	141.24	49210.80	0.00	49210.70	2054.90	0.00	23.40	4.80	332.00	21.59	663.80	50.36	185.5	23.25	34.60	5.54	0.00	0.00	10.01	38.50	4680.00	21036.00	49062.00	22646.40
Min	36*	301.35	9708.80	79.00	93.10	49246.00	0.00	49246.00	2074.00	0.00	22.00	4.53	338.00	21.88	662.00	50.55	185.0	23.04	34.00	5.44	0.00	0.00	9.97	41.00	4400.00	21240.00	49080.00	22368.00
Max	36*	317.04	9775.20	80.00	137.06	47916.00	0.00	47916.00	1938.00	0.00	24.00	4.91	348.00	21.91	660.00	49.90	186.0	23.28	40.00	6.40	0.00	0.00	10.95	41.00	4800.00	21420.00	48780.00	22752.00
Case 6																												
Mean	1	300.47	10576.56	78.60	167.65	5171.00	0.00	5171.00	0.60	0.00	46.20	8.74	248.60	13.46	763.80	56.42	195.1	21.38	29.90	6.83	0.00	0.00	9.61	36.10	9240.00	14238.00	59670.00	22617.60
Min	1	300.57	10553.60	80.00	234.03	5152.00	0.00	5152.00	1.00	0.00	40.00	7.58	244.00	13.30	770.00	57.42	195.0	21.70	28.00	6.39	0.00	0.00	8.57	29.00	8000.00	14040.00	60600.00	22896.00
Max	1	300.60	10600.40	78.00	175.19	5165.00	0.00	5165.00	1.00	0.00	42.00	7.92	244.00	13.55	768.00	56.88	194.0	21.64	34.00	7.76	0.00	0.00	10.16	35.00	8400.00	14360.00	60300.00	22944.00
Mean	12	300.50	10538.72	79.20	131.52	53852.80	0.00	53852.80	6.70	0.00	42.40	8.02	245.60	13.37	767.60	56.97	192.4	21.31	30.40	6.94	0.00	0.00	9.13	37.20	8480.00	14136.00	60240.00	22531.20
Min	12	300.63	10486.80	78.00	277.51	54835.00	0.00	54835.00	9.00	0.00	46.00	8.72	248.00	13.34	764.00	56.56	189.0	20.74	32.00	7.31	0.00	0.00	10.00	43.00	9200.00	14080.00	59700.00	21888.00
Max	12	300.64	10568.00	79.00	1.72	54395.00	0.00	54395.00	7.00	0.00	40.00	7.55	252.00	13.48	770.00	57.19	194.0	21.52	31.00	7.08	0.00	0.00	8.84	39.00	8000.00	14280.00	60600.00	22800.00
Mean	36	310.41	10534.76	78.00	133.11	57764.00	0.00	57764.00	7.70	0.00	42.80	8.07	247.80	13.49	765.60	56.66	191.2	21.12	30.10	6.87	0.00	0.00	9.56	36.50	8560.00	14302.00	60084.00	22401.60
Min	36	307.46	10493.20	78.00	18.03	55484.00	0.00	55484.00	7.00	0.00	44.00	8.35	254.00	14.05	758.00	56.45	185.0	20.67	26.00	5.94	0.00	0.00	10.30	34.00	8800.00	14820.00	59520.00	21792.00
Max	36	311.63	10555.60	78.00	101.49	57045.00	0.00	57045.00	11.00	0.00	44.00	8.27	242.00	13.25	766.00	56.40	194.0	21.30	27.00	6.16	0.00	0.00	8.16	37.00	8800.00	14100.00	60000.00	22656.00
Mean	36*	303.45	10535.28	78.40	144.94	54634.00	0.00	54634.00	7.60	0.00	43.80	8.31	249.20	13.67	763.40	56.82	190.4	21.19	31.10	7.10	0.00	0.00	9.36	35.10	8760.00	14406.00	59862.00	22324.80
Min	36*	301.28	10493.20	78.00	8.13	53083.00	0.00	53083.00	14.00	0.00	44.00	8.39	254.00	14.12	758.00	56.72	185.0	20.77	26.00	5.94	0.00	0.00	10.30	34.00	8800.00	14820.00	59520.00	21792.00
Max	36*	301.00	10557.60	79.00	256.46	54898.00	0.00	54898.00	14.00	0.00	48.00	9.09	248.00	13.64	762.00	56.26	189.0	21.00	32.00	7.31	0.00	0.00	9.59	37.00	9600.00	14400.00	59400.00	22176.00

Table E.23: Results of the best results of EON network cases 4, 5 and 6, for 300 seconds.

OPERATIONS	COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
	$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	#10G	%10G	#40G	%40G	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
Case 7																												
Mean	1	300.58	11884.72	80.00	194.71	1811.80	0.00	1811.80	481.50	0.00	17.60	2.96	772.80	38.26	452.00	31.03	255.8	27.76	60.30	3.86	0.00	0.00	6.44	33.40	3520.00	45476.00	36876.00	32995.20
Min	1	300.66	11799.60	80.00	156.00	1820.00	0.00	1820.00	488.00	0.00	14.00	2.37	762.00	37.75	464.00	32.14	251.0	27.74	60.00	3.84	0.00	0.00	5.05	31.00	2800.00	44540.00	37920.00	32736.00
Max	1	300.69	11914.00	80.00	103.62	1805.00	0.00	1805.00	465.00	0.00	18.00	3.02	772.00	38.46	444.00	30.52	259.0	28.00	56.00	3.58	0.00	0.00	6.73	33.00	3600.00	45820.00	36360.00	33360.00
Mean	12	300.79	11836.36	80.00	131.79	19060.00	0.00	19060.00	5194.20	0.00	20.40	3.43	765.60	37.63	455.80	30.95	254.8	27.40	59.00	3.77	0.00	0.00	6.75	34.70	4080.00	44806.00	36852.00	32625.60
Min	12	300.69	11769.20	80.00	108.93	19484.00	0.00	19484.00	5279.00	0.00	20.00	3.35	752.00	36.51	466.00	31.40	254.0	27.29	57.00	3.65	0.00	0.00	6.81	33.00	4000.00	43600.00	37500.00	32592.00
Max	12	300.80	11872.80	80.00	280.43	19026.00	0.00	19026.00	5230.00	0.00	18.00	3.02	774.00	37.65	456.00	31.11	257.0	27.83	51.00	3.26	0.00	0.00	7.16	32.00	3600.00	44880.00	37080.00	33168.00
Mean	36	312.58	11829.32	80.00	144.12	20505.60	0.00	20505.60	5568.30	0.00	20.00	3.35	772.60	37.37	457.00	30.91	256.8	27.32	58.30	3.73	0.00	0.00	6.43	32.60	4000.00	44674.00	36960.00	32659.20
Min	36	313.74	11753.20	80.00	52.52	20508.00	0.00	20508.00	5559.00	0.00	24.00	4.03	758.00	36.88	458.00	30.76	258.0	26.94	54.00	3.45	0.00	0.00	5.76	41.00	4800.00	43960.00	36660.00	32112.00
Max	36	309.58	11871.20	80.00	178.85	20201.00	0.00	20201.00	5507.00	0.00	20.00	3.34	770.00	37.90	446.00	30.34	256.0	27.65	51.00	3.26	0.00	0.00	6.05	40.00	4000.00	45340.00	36300.00	33072.00
Mean	36*	303.76	11810.20	80.00	177.13	19503.50	0.00	19503.50	5309.60	0.00	21.40	3.62	766.80	38.19	451.40	30.90	253.2	27.31	59.80	3.83	0.00	0.00	6.58	34.70	4280.00	45108.00	36498.00	32256.00
Min	36*	301.49	11753.20	80.00	55.71	19176.00	0.00	19176.00	5003.00	0.00	24.00	4.08	758.00	37.40	458.00	31.19	258.0	27.32	54.00	3.45	0.00	0.00	5.76	41.00	4800.00	43960.00	36660.00	32112.00
Max	36*	311.27	11849.20	80.00	227.50	20044.00	0.00	20044.00	5463.00	0.00	20.00	3.38	772.00	38.57	450.00	30.84	253.0	27.30	62.00	3.97	0.00	0.00	6.11	42.00	4000.00	45700.00	36540.00	32352.00
Case 8																												
Mean	1	300.58	12158.60	77.50	124.80	2713.90	0.00	1578.70	0.10	0.00	37.40	6.15	388.80	18.63	864.60	51.59	266.1	23.63	40.40	5.17	0.00	0.00	10.01	45.00	7480.00	22648.00	62730.00	28728.00
Min	1	300.75	12117.20	80.00	158.33	2732.00	0.00	1613.00	0.00	0.00	42.00	6.93	394.00	18.73	860.00	51.20	262.0	23.13	39.00	4.99	0.00	0.00	9.84	49.00	8400.00	22700.00	62040.00	28032.00
Max	1	300.35	12180.40	74.00	194.50	2708.00	0.00	1569.00	0.00	0.00	38.00	6.24	386.00	18.57	864.00	51.43	264.0	23.76	37.00	4.73	0.00	0.00	10.46	44.00	7600.00	22620.00	62640.00	28944.00
Mean	12	300.61	12121.68	78.10	131.77	28393.50	0.00	16550.50	0.20	0.00	36.80	6.05	388.00	18.66	865.20	51.68	259.9	23.32	39.10	5.00	0.00	0.00	9.61	44.20	7360.00	22688.00	62820.00	28348.80
Min	12	300.55	12095.60	77.00	156.55	28963.00	0.00	16976.00	0.00	0.00	40.00	6.61	376.00	18.55	862.00	51.54	256.0	23.29	32.00	4.09	0.00	0.00	9.00	41.00	8000.00	22440.00	62340.00	28176.00
Max	12	300.50	12160.80	78.00	82.46	26429.00	0.00	15493.00	0.00	0.00	40.00	6.57	390.00	18.61	862.00	51.20	265.0	23.50	38.00	4.86	0.00	0.00	9.92	46.00	8000.00	22660.00	62340.00	28608.00
Mean	36	312.94	12125.16	78.10	157.22	31013.30	0.00	18090.10	0.50	0.00	36.80	6.03	387.00	18.50	865.20	51.49	263.7	23.36	39.80	5.09	0.00	0.00	9.62	43.90	7360.00	22574.00	62820.00	28497.60
Min	36	315.54	12095.20	78.00	213.13	31279.00	0.00	18166.00	0.00	0.00	40.00	6.57	382.00	18.55	862.00	51.22	259.0	23.03	41.00	5.24	0.00	0.00	10.97	54.00	8000.00	22580.00	62340.00	28032.00
Max	36	312.48	12143.20	77.00	212.66	30654.00	0.00	17828.00	1.00	0.00	38.00	6.22	392.00	18.35	864.00	51.23	271.0	23.52	42.00	5.37	0.00	0.00	9.81	42.00	7600.00	22440.00	62640.00	28752.00
Mean	36*	301.29	12109.44	78.00	130.24	29302.40	0.00	17078.20	0.50	0.00	34.60	5.71	389.80	18.72	867.40	52.15	260.9	23.42	41.40	5.29	0.00	0.00	9.71	42.70	6920.00	22666.00	63150.00	28358.40
Min	36*	301.56	12063.60	77.00	19.24	29766.00	0.00	17333.00	0.00	0.00	34.00	5.64	382.00	18.98	868.00	52.42	248.0	22.96	39.00	4.99	0.00	0.00	10.51	37.00	6800.00	22900.00	63240.00	27696.00
Max	36*	301.44	12135.20	80.00	237.29	27287.00	0.00	15923.00	1.00	0.00	40.00	6.59	390.00	18.54	862.00	51.37	270.0	23.50	48.00	6.14	0.00	0.00	9.08	39.00	8000.00	22500.00	62340.00	28512.00
Case 9																												
Mean	1	300.64	14580.56	80.00	178.24	1643.20	0.00	1643.20	30.90	0.00	48.20	6.61	315.80	12.57	964.40	52.14	353.1	28.68	51.90	9.47	0.00	0.00	8.46	36.00	9640.00	18322.00	76026.00	41817.60
Min	1	300.39	14506.80	80.00	192.55	1643.00	0.00	1643.00	28.00	0.00	52.00	7.17	306.00	11.77	970.00	52.40	355.0	28.65	47.00	8.58	0.00	0.00	9.32	35.00	10400.00	17080.00	76020.00	41568.00
Max	1	300.44	14657.20	80.00	122.82	1647.00	0.00	1647.00	31.00	0.00	46.00	6.28	304.00	12.13	976.00	52.48	356.0	29.11	55.00	10.04	0.00	0.00	7.62	41.00	9200.00	17780.00	76920.00	42672.00
Mean	12	300.88	14534.84	80.00	122.00	17476.30	0.00	17476.30	343.40	0.00	46.80	6.42	315.00	12.57	964.80	52.24	347.4	28.45	49.70	9.07	0.00	0.00	8.57	36.60	9360.00	18326.00	76176.00	41486.40
Min	12	302.22	14499.20	80.00	147.65	17053.00	0.00	17053.00	334.00	0.00	44.00	6.02	320.00	12.47	970.00	52.52	350.0	28.22	47.00	8.58	0.00	0.00	9.73	38.00	8800.00	18220.00	76740.00	41232.00
Max	12	300.60	14560.00	80.00	277.24	17617.00	0.00	17617.00	351.00	0.00	44.00	6.04	320.00	12.40	970.00	52.71	355.0	28.85	49.00	8.94	0.00	0.00	9.97	43.00	8800.00	18060.00	76740.00	42000.00
Mean	36	312.29	14504.44	80.00	164.60	18540.30	0.00	18540.30	350.30	0.00	47.40	6.47	314.40	12.25	967.40	52.08	349.2	28.23	48.30	8.81	0.00	0.00	8.31	37.50	9480.00	17944.00	76278.00	41342.40
Min	36	316.10	14436.40	80.00	72.93	18699.00	0.00	18699.00	358.00	0.00	36.00	4.90	326.00	12.29	978.00	53.08	345.0	28.05	47.00	8.58	0.00	0.00	7.51	28.00	7200.00	18040.00	77940.00	41184.00
Max	36	311.49	14541.60	80.00	16.80	17412.00	0.00	17412.00	329.00	0.00	46.00	6.26	326.00	11.87	976.00	52.37	355.0	28.49	47.00	8.58	0.00	0.00	9.00	43.00	9200.00	17440.00	76920.00	41856.00
Mean	36*	302.23	14504.40	80.00	230.68	17604.50	0.00	17604.50	344.10	0.00	47.40	6.54	314.60	12.50	966.60	52.56	346.3	28.41	48.70	8.89	0.00	0.00	8.08	35.90	9480.00	18126.00	76230.00	41208.00
Min	36*	301.52	14422.00	80.00	209.90	16778.00	0.00	16778.00	337.00	0.00	44.00	6.10	318.00	12.56	970.00	53.21	340.0	28.12	50.00	9.12	0.00	0.00	7.65	34.00	8800.00	18120.00	76740.00	40560.00
Max	36*	301.69	14570.00	80.00	245.28	17773.00	0.00	17773.00	342.00	0.00	54.00	7.41	312.00	12.45	960.00	51.64	344.0	28.50	51.00	9.31	0.00	0.00	6.86	33.00	10800.00	18140.00	75240.00	41520.00

Table E.24: Results of the best results of EON network cases 7, 8 and 9, for 300 seconds.

E.7 GBN best results for 300 seconds.

Symbol	Name
$\#T$	Number of Threads
t_E	Time of Execution
C	Best Cost Solution found
CA	Highest Channel Assigned
t_{sol}	Found Solution Time
$\#i$	Number of Iterations
$\#IS$	Number of Invalid Solutions
$\#G_U$	Number of Greedy Solutions Unfeasible
$\#LS_U$	Number of Local Search Solutions Unfeasible
UD	Unfeasible Degree
$\#IM$	Number of Invert Multiplex used
C_{IM}	Cost % of Invert Multiplex
$\#MX$	Number of Muxponders placed
C_{MX}	Cost % of Muxponders
$\#TX$	Number of Transponders placed
C_{TX}	Cost % of Transponders
$\#3R$	Number of $3R$ regenerators placed
C_{3R}	Cost % of $3R$ regenerators
$\#10$	Number of Multi-Hop Grooming of $10Gb/s$
$\%10$	Traffic % of Multi-Hop Grooming of $10Gb/s$
$\#40$	Number of Multi-hop Grooming of $40Gb/s$
$\%40$	Traffic % of Multi-hop Grooming of $40Gb/s$
$\bar{m}F$	Average Fragmentation at Channel Assigned
MF	Max Fragmentation at Channel Assigned
C_{IM}	Cost of Invert Multiplexers
C_{MX}	Cost of Multiplexers
C_{TX}	Cost of Transponders
C_{3R}	Cost of $3R$ regenerators

Table E.25: Header symbols and their description.

OPERATIONS	COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
	$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	#10G	%10G	#40G	%40G	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
Case 1																												
Mean	1	300.24	4731.20	59.40	160.99	46871.40	0.00	0.00	0.00	0.00	0.00	0.00	465.60	49.27	280.00	50.73	0.0	0.00	10.20	1.13	0.00	0.00	12.23	30.90	0.00	23312.00	24000.00	0.00
Min	1	300.19	4730.00	57.00	184.77	46850.00	0.00	0.00	0.00	0.00	0.00	0.00	466.00	49.26	280.00	50.74	0.0	0.00	13.00	1.44	0.00	0.00	10.54	25.00	0.00	23300.00	24000.00	0.00
Max	1	300.33	4736.00	57.00	70.53	46837.00	0.00	0.00	0.00	0.00	0.00	0.00	464.00	49.32	280.00	50.68	0.0	0.00	9.00	1.00	0.00	0.00	9.27	29.00	0.00	23360.00	24000.00	0.00
Mean	12	300.37	4730.00	57.20	111.36	457708.80	0.00	0.00	0.00	0.00	0.00	0.00	466.00	49.25	280.00	50.73	0.0	0.00	10.60	1.18	0.00	0.00	11.27	28.10	0.00	23300.00	24000.00	0.00
Min	12	300.33	4730.00	56.00	73.77	447898.00	0.00	0.00	0.00	0.00	0.00	0.00	466.00	49.26	280.00	50.74	0.0	0.00	10.00	1.11	0.00	0.00	11.35	34.00	0.00	23300.00	24000.00	0.00
Max	12	300.35	4730.00	59.00	291.25	451051.00	0.00	0.00	0.00	0.00	0.00	0.00	466.00	49.26	280.00	50.74	0.0	0.00	11.00	1.22	0.00	0.00	10.92	29.00	0.00	23300.00	24000.00	0.00
Mean	36	312.13	4729.20	56.80	130.37	509576.30	0.00	0.00	0.00	0.00	0.00	0.00	465.20	49.20	280.00	50.69	0.0	0.00	9.90	1.10	0.00	0.00	10.78	28.70	0.00	23292.00	24000.00	0.00
Min	36	313.73	4726.00	56.00	145.33	504218.00	0.00	0.00	0.00	0.00	0.00	0.00	462.00	49.11	280.00	50.68	0.0	0.00	12.00	1.33	0.00	0.00	12.19	30.00	0.00	23260.00	24000.00	0.00
Max	36	307.44	4730.00	57.00	218.09	508153.00	0.00	0.00	0.00	0.00	0.00	0.00	466.00	49.20	280.00	50.68	0.0	0.00	10.00	1.11	0.00	0.00	10.27	35.00	0.00	23300.00	24000.00	0.00
Mean	36*	309.41	4730.00	56.80	134.19	492309.00	0.00	0.00	0.00	0.00	0.00	0.00	466.00	49.26	280.00	50.74	0.0	0.00	9.70	1.08	0.00	0.00	11.43	26.70	0.00	23300.00	24000.00	0.00
Min	36*	313.89	4730.00	56.00	46.25	493418.00	0.00	0.00	0.00	0.00	0.00	0.00	466.00	49.26	280.00	50.74	0.0	0.00	9.00	1.00	0.00	0.00	10.12	24.00	0.00	23300.00	24000.00	0.00
Max	36*	313.86	4730.00	58.00	254.08	481808.00	0.00	0.00	0.00	0.00	0.00	0.00	466.00	49.26	280.00	50.74	0.0	0.00	11.00	1.22	0.00	0.00	13.62	35.00	0.00	23300.00	24000.00	0.00
Case 2																												
Mean	1	300.29	5178.00	72.80	81.49	51832.90	0.00	1808.30	132.10	0.00	0.00	0.00	212.00	22.94	530.00	77.06	0.0	0.00	8.50	1.89	0.00	0.00	15.76	34.80	0.00	11880.00	39900.00	0.00
Min	1	300.21	5178.00	72.00	78.56	52321.00	0.00	1796.00	132.00	0.00	0.00	0.00	212.00	22.94	530.00	77.06	0.0	0.00	11.00	2.44	0.00	0.00	15.42	36.00	0.00	11880.00	39900.00	0.00
Max	1	300.19	5178.00	74.00	116.38	51992.00	0.00	1855.00	136.00	0.00	0.00	0.00	212.00	22.94	530.00	77.06	0.0	0.00	7.00	1.56	0.00	0.00	16.42	35.00	0.00	11880.00	39900.00	0.00
Mean	12	300.29	5176.80	73.20	127.25	454727.00	6.60	15780.90	1119.20	0.00	0.00	0.00	207.60	22.92	530.00	77.06	0.0	0.00	8.70	1.93	0.00	0.00	15.97	36.60	0.00	11868.00	39900.00	0.00
Min	12	300.38	5174.00	73.00	264.42	504188.00	0.00	17702.00	1285.00	0.00	0.00	0.00	208.00	22.87	530.00	77.06	0.0	0.00	8.00	1.78	0.00	0.00	16.92	40.00	0.00	11840.00	39900.00	0.00
Max	12	300.21	5178.00	72.00	100.53	453330.00	0.00	15903.00	1110.00	0.00	0.00	0.00	212.00	22.94	530.00	77.06	0.0	0.00	7.00	1.56	0.00	0.00	16.00	45.00	0.00	11880.00	39900.00	0.00
Mean	36	312.44	5176.60	73.50	121.99	491954.20	0.00	17189.80	1214.50	0.00	0.00	0.00	206.60	22.92	530.00	77.05	0.0	0.00	8.30	1.84	0.00	0.00	16.29	37.30	0.00	11866.00	39900.00	0.00
Min	36	316.20	5174.00	76.00	209.65	486238.00	0.00	17008.00	1225.00	0.00	0.00	0.00	208.00	22.87	530.00	77.06	0.0	0.00	9.00	2.00	0.00	0.00	16.58	41.00	0.00	11840.00	39900.00	0.00
Max	36	307.15	5178.00	72.00	78.42	491629.00	0.00	17109.00	1226.00	0.00	0.00	0.00	212.00	22.94	530.00	77.06	0.0	0.00	10.00	2.22	0.00	0.00	16.81	38.00	0.00	11880.00	39900.00	0.00
Mean	36*	308.08	5176.60	73.90	83.37	472306.30	0.00	16466.20	1160.30	0.00	0.00	0.00	206.60	22.92	530.00	77.08	0.0	0.00	8.30	1.84	0.00	0.00	15.54	36.00	0.00	11866.00	39900.00	0.00
Min	36*	310.19	5174.00	76.00	97.38	523424.00	0.00	18273.00	1286.00	0.00	0.00	0.00	208.00	22.88	530.00	77.12	0.0	0.00	7.00	1.56	0.00	0.00	12.50	30.00	0.00	11840.00	39900.00	0.00
Max	36*	301.11	5178.00	72.00	109.82	454711.00	0.00	15999.00	1165.00	0.00	0.00	0.00	212.00	22.94	530.00	77.06	0.0	0.00	10.00	2.22	0.00	0.00	13.42	24.00	0.00	11880.00	39900.00	0.00
Case 3																												
Mean	1	300.29	5569.20	58.70	155.67	46235.00	0.00	0.00	0.00	0.00	0.00	0.00	149.20	14.89	580.00	85.11	0.0	0.00	13.60	4.53	0.00	0.00	13.21	34.40	0.00	8292.00	47400.00	0.00
Min	1	300.35	5566.00	58.00	254.56	46450.00	0.00	0.00	0.00	0.00	0.00	0.00	146.00	14.84	580.00	85.16	0.0	0.00	15.00	5.00	0.00	0.00	13.50	41.00	0.00	8260.00	47400.00	0.00
Max	1	300.19	5570.00	61.00	25.90	45947.00	0.00	0.00	0.00	0.00	0.00	0.00	150.00	14.90	580.00	85.10	0.0	0.00	12.00	4.00	0.00	0.00	12.73	39.00	0.00	8300.00	47400.00	0.00
Mean	12	300.29	5566.40	58.50	118.22	438935.10	0.00	0.00	0.00	0.00	0.00	0.00	146.40	14.84	580.00	85.10	0.0	0.00	12.90	4.30	0.00	0.00	12.39	34.40	0.00	8264.00	47400.00	0.00
Min	12	300.21	5566.00	57.00	82.31	422126.00	0.00	0.00	0.00	0.00	0.00	0.00	146.00	14.83	580.00	85.10	0.0	0.00	13.00	4.33	0.00	0.00	9.77	37.00	0.00	8260.00	47400.00	0.00
Max	12	300.36	5570.00	57.00	122.93	432093.00	0.00	0.00	0.00	0.00	0.00	0.00	150.00	14.90	580.00	85.10	0.0	0.00	13.00	4.33	0.00	0.00	10.15	37.00	0.00	8300.00	47400.00	0.00
Mean	36	310.78	5566.00	58.10	117.62	497720.60	0.00	0.00	0.00	0.00	0.00	0.00	146.00	14.82	580.00	85.05	0.0	0.00	12.90	4.30	0.00	0.00	12.48	30.50	0.00	8260.00	47400.00	0.00
Min	36	306.02	5566.00	55.00	178.12	493897.00	0.00	0.00	0.00	0.00	0.00	0.00	146.00	14.83	580.00	85.10	0.0	0.00	11.00	3.67	0.00	0.00	10.69	23.00	0.00	8260.00	47400.00	0.00
Max	36	313.11	5566.00	62.00	214.06	498166.00	0.00	0.00	0.00	0.00	0.00	0.00	146.00	14.82	580.00	85.04	0.0	0.00	13.00	4.33	0.00	0.00	14.69	30.00	0.00	8260.00	47400.00	0.00
Mean	36*	311.45	5566.00	59.10	130.72	482905.70	0.00	0.00	0.00	0.00	0.00	0.00	146.00	14.84	580.00	85.16	0.0	0.00	12.20	4.07	0.00	0.00	12.74	33.50	0.00	8260.00	47400.00	0.00
Min	36*	308.74	5566.00	57.00	93.79	484729.00	0.00	0.00	0.00	0.00	0.00	0.00	146.00	14.84	580.00	85.16	0.0	0.00	12.00	4.00	0.00	0.00	13.27	37.00	0.00	8260.00	47400.00	0.00
Max	36*	313.50	5566.00	63.00	44.29	477793.00	0.00	0.00	0.00	0.00	0.00	0.00	146.00	14.84	580.00	85.16	0.0	0.00	13.00	4.33	0.00	0.00	17.08	42.00	0.00	8260.00	47400.00	0.00

Table E.26: Results of the best results of GBN network cases 1, 2 and 3, for 300 seconds.

OPERATIONS	COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
	$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	#10G	%10G	#40G	%40G	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
Case 4																												
Mean	1	300.34	5689.00	78.50	131.56	20160.20	0.00	8980.20	1292.40	0.00	0.00	0.00	545.80	49.38	336.00	50.62	0.0	0.00	21.00	1.94	0.00	0.00	12.30	31.80	0.00	28090.00	28800.00	0.00
Min	1	300.44	5686.00	77.00	58.84	20203.00	0.00	9019.00	1317.00	0.00	0.00	0.00	542.00	49.35	336.00	50.65	0.0	0.00	22.00	2.04	0.00	0.00	10.38	25.00	0.00	28060.00	28800.00	0.00
Max	1	300.42	5692.00	80.00	108.78	20222.00	0.00	8920.00	1302.00	0.00	0.00	0.00	556.00	49.40	336.00	50.60	0.0	0.00	26.00	2.41	0.00	0.00	12.65	33.00	0.00	28120.00	28800.00	0.00
Mean	12	300.37	5684.80	78.70	186.62	196558.50	0.00	87809.40	12537.80	0.00	0.00	0.00	547.20	49.29	336.00	50.61	0.0	0.00	18.70	1.73	0.00	0.00	12.72	33.80	0.00	28048.00	28800.00	0.00
Min	12	300.44	5680.00	77.00	89.33	199888.00	0.00	89432.00	12639.00	0.00	0.00	0.00	544.00	49.21	336.00	50.62	0.0	0.00	17.00	1.57	0.00	0.00	13.54	31.00	0.00	28000.00	28800.00	0.00
Max	12	300.27	5688.00	80.00	100.99	197017.00	0.00	87892.00	12503.00	0.00	0.00	0.00	552.00	49.35	336.00	50.62	0.0	0.00	18.00	1.67	0.00	0.00	11.92	34.00	0.00	28080.00	28800.00	0.00
Mean	36	312.70	5685.00	78.10	167.16	206312.00	0.00	92192.50	13147.70	0.00	0.00	0.00	545.00	49.26	336.00	50.57	0.0	0.00	19.80	1.83	0.00	0.00	12.72	30.50	0.00	28050.00	28800.00	0.00
Min	36	309.54	5682.00	79.00	156.41	205291.00	0.00	91537.00	13061.00	0.00	0.00	0.00	538.00	49.19	336.00	50.56	0.0	0.00	18.00	1.67	0.00	0.00	13.23	37.00	0.00	28020.00	28800.00	0.00
Max	36	309.39	5688.00	79.00	137.84	207600.00	0.00	92672.00	13220.00	0.00	0.00	0.00	552.00	49.33	336.00	50.60	0.0	0.00	20.00	1.85	0.00	0.00	13.04	30.00	0.00	28080.00	28800.00	0.00
Mean	36*	308.29	5685.60	77.70	109.22	203304.00	0.00	90702.50	12951.70	0.00	0.00	0.00	544.80	49.35	336.00	50.65	0.0	0.00	19.60	1.81	0.00	0.00	12.80	33.50	0.00	28056.00	28800.00	0.00
Min	36*	313.76	5684.00	77.00	18.78	212292.00	0.00	94820.00	13476.00	0.00	0.00	0.00	548.00	49.33	336.00	50.67	0.0	0.00	17.00	1.57	0.00	0.00	12.65	37.00	0.00	28040.00	28800.00	0.00
Max	36*	306.95	5688.00	78.00	118.75	205486.00	0.00	91671.00	13078.00	0.00	0.00	0.00	552.00	49.37	336.00	50.63	0.0	0.00	21.00	1.94	0.00	0.00	12.77	29.00	0.00	28080.00	28800.00	0.00
Case 5																												
Mean	1	300.33	6231.60	78.30	96.32	17176.80	0.00	14731.10	1015.90	0.00	0.00	0.00	253.20	23.17	636.00	76.83	0.0	0.00	14.50	2.69	0.00	0.00	11.99	36.60	0.00	14436.00	47880.00	0.00
Min	1	300.44	6228.00	78.00	180.35	17206.00	0.00	14711.00	975.00	0.00	0.00	0.00	256.00	23.12	636.00	76.88	0.0	0.00	16.00	2.96	0.00	0.00	12.00	37.00	0.00	14400.00	47880.00	0.00
Max	1	300.24	6234.00	79.00	3.65	17119.00	0.00	14776.00	1042.00	0.00	0.00	0.00	254.00	23.20	636.00	76.80	0.0	0.00	18.00	3.33	0.00	0.00	11.77	36.00	0.00	14460.00	47880.00	0.00
Mean	12	300.39	6227.20	78.60	118.80	165906.90	0.00	142465.80	9901.40	0.00	0.00	0.00	258.40	23.09	636.00	76.81	0.0	0.00	14.90	2.76	0.00	0.00	11.65	38.30	0.00	14392.00	47880.00	0.00
Min	12	300.27	6224.00	78.00	84.91	175880.00	0.00	151009.00	10387.00	0.00	0.00	0.00	252.00	23.04	636.00	76.80	0.0	0.00	14.00	2.59	0.00	0.00	12.38	36.00	0.00	14360.00	47880.00	0.00
Max	12	300.47	6232.00	78.00	196.56	167564.00	0.00	143868.00	10037.00	0.00	0.00	0.00	260.00	23.17	636.00	76.83	0.0	0.00	15.00	2.78	0.00	0.00	11.85	32.00	0.00	14440.00	47880.00	0.00
Mean	36	314.46	6228.00	79.00	124.00	184143.50	0.00	158096.60	10988.70	0.00	0.00	0.00	256.00	23.08	636.00	76.76	0.0	0.00	14.90	2.76	0.00	0.00	11.25	34.90	0.00	14400.00	47880.00	0.00
Min	36	314.64	6226.00	80.00	69.72	183875.00	0.00	157862.00	11066.00	0.00	0.00	0.00	262.00	23.04	636.00	76.73	0.0	0.00	14.00	2.59	0.00	0.00	10.77	36.00	0.00	14380.00	47880.00	0.00
Max	36	315.32	6230.00	80.00	239.38	180748.00	0.00	155231.00	10805.00	0.00	0.00	0.00	250.00	23.12	636.00	76.76	0.0	0.00	15.00	2.78	0.00	0.00	11.73	38.00	0.00	14420.00	47880.00	0.00
Mean	36*	304.92	6227.20	79.00	139.67	174008.30	0.00	149415.50	10385.40	0.00	0.00	0.00	256.80	23.11	636.00	76.89	0.0	0.00	15.20	2.81	0.00	0.00	11.72	38.30	0.00	14392.00	47880.00	0.00
Min	36*	301.14	6224.00	79.00	195.70	178437.00	0.00	153079.00	10599.00	0.00	0.00	0.00	252.00	23.07	636.00	76.93	0.0	0.00	15.00	2.78	0.00	0.00	12.12	44.00	0.00	14360.00	47880.00	0.00
Max	36*	300.88	6230.00	79.00	11.44	178234.00	0.00	153292.00	10698.00	0.00	0.00	0.00	250.00	23.15	636.00	76.85	0.0	0.00	15.00	2.78	0.00	0.00	10.38	34.00	0.00	14420.00	47880.00	0.00
Case 6																												
Mean	1	300.34	6706.60	72.60	143.51	22266.70	0.00	178.90	0.00	0.00	0.00	0.00	190.60	15.19	696.00	84.81	0.0	0.00	20.90	5.81	0.00	0.00	12.39	28.00	0.00	10186.00	56880.00	0.00
Min	1	300.27	6698.00	71.00	280.54	22266.00	0.00	195.00	0.00	0.00	0.00	0.00	186.00	15.08	696.00	84.92	0.0	0.00	19.00	5.28	0.00	0.00	12.15	28.00	0.00	10100.00	56880.00	0.00
Max	1	300.46	6712.00	71.00	1.58	22324.00	0.00	177.00	0.00	0.00	0.00	0.00	192.00	15.26	696.00	84.74	0.0	0.00	24.00	6.67	0.00	0.00	12.31	25.00	0.00	10240.00	56880.00	0.00
Mean	12	300.44	6699.00	72.00	187.88	220310.70	0.00	1774.20	0.00	0.00	0.00	0.00	189.40	15.07	696.00	84.80	0.0	0.00	21.10	5.86	0.00	0.00	12.08	29.60	0.00	10110.00	56880.00	0.00
Min	12	300.39	6692.00	73.00	32.28	225541.00	0.00	1827.00	0.00	0.00	0.00	0.00	188.00	14.97	696.00	84.79	0.0	0.00	21.00	5.83	0.00	0.00	12.35	31.00	0.00	10040.00	56880.00	0.00
Max	12	301.06	6702.00	74.00	286.98	229326.00	0.00	1823.00	0.00	0.00	0.00	0.00	190.00	15.12	696.00	84.79	0.0	0.00	24.00	6.67	0.00	0.00	10.62	24.00	0.00	10140.00	56880.00	0.00
Mean	36	311.34	6700.40	72.00	130.67	241024.00	0.00	1902.70	0.00	0.00	0.00	0.00	190.00	15.09	696.00	84.76	0.0	0.00	21.00	5.83	0.00	0.00	12.15	31.20	0.00	10124.00	56880.00	0.00
Min	36	301.55	6698.00	71.00	32.85	235878.00	0.00	1889.00	0.00	0.00	0.00	0.00	186.00	15.05	696.00	84.74	0.0	0.00	22.00	6.11	0.00	0.00	11.04	30.00	0.00	10100.00	56880.00	0.00
Max	36	317.69	6702.00	73.00	251.85	241646.00	0.00	1839.00	0.00	0.00	0.00	0.00	190.00	15.10	696.00	84.69	0.0	0.00	21.00	5.83	0.00	0.00	9.35	31.00	0.00	10140.00	56880.00	0.00
Mean	36*	301.63	6701.00	72.10	111.57	231864.60	0.00	1860.70	0.00	0.00	0.00	0.00	189.80	15.12	696.00	84.88	0.0	0.00	19.50	5.42	0.00	0.00	12.18	31.10	0.00	10130.00	56880.00	0.00
Min	36*	301.38	6698.00	71.00	175.63	231911.00	0.00	1892.00	0.00	0.00	0.00	0.00	186.00	15.08	696.00	84.92	0.0	0.00	22.00	6.11	0.00	0.00	11.04	30.00	0.00	10100.00	56880.00	0.00
Max	36*	301.02	6702.00	76.00	106.30	236356.00	0.00	1864.00	0.00	0.00	0.00	0.00	190.00	15.13	696.00	84.87	0.0	0.00	17.00	4.72	0.00	0.00	9.12	21.00	0.00	10140.00	56880.00	0.00

Table E.27: Results of the best results of GBN network cases 4, 5 and 6, for 300 seconds.

OPERATIONS	COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
	$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
Case 7																												
Mean	1	300.38	6618.00	80.00	179.29	10405.30	0.00	10405.30	6864.50	0.00	0.00	0.00	566.80	49.59	388.00	50.41	0.0	0.00	27.40	2.21	0.00	0.00	10.02	32.50	0.00	32820.00	33360.00	0.00
Min	1	300.28	6604.00	80.00	98.67	10343.00	0.00	10343.00	6804.00	0.00	0.00	0.00	564.00	49.49	388.00	50.51	0.0	0.00	30.00	2.42	0.00	0.00	10.27	31.00	0.00	32680.00	33360.00	0.00
Max	1	300.32	6626.00	80.00	93.16	10208.00	0.00	10208.00	6623.00	0.00	0.00	0.00	562.00	49.65	388.00	50.35	0.0	0.00	25.00	2.01	0.00	0.00	10.27	34.00	0.00	32900.00	33360.00	0.00
Mean	12	300.47	6607.20	80.00	124.54	104677.40	0.00	104677.40	69091.20	0.00	0.00	0.00	567.20	49.45	388.00	50.43	0.0	0.00	27.50	2.21	0.00	0.00	9.96	31.40	0.00	32712.00	33360.00	0.00
Min	12	300.58	6596.00	80.00	142.46	106344.00	0.00	106344.00	70422.00	0.00	0.00	0.00	572.00	49.42	388.00	50.58	0.0	0.00	27.00	2.17	0.00	0.00	9.38	26.00	0.00	32600.00	33360.00	0.00
Max	12	300.58	6616.00	80.00	69.08	105387.00	0.00	105387.00	69638.00	0.00	0.00	0.00	576.00	49.53	388.00	50.38	0.0	0.00	29.00	2.33	0.00	0.00	7.12	23.00	0.00	32800.00	33360.00	0.00
Mean	36	312.34	6608.00	80.00	138.89	105517.80	0.00	105517.80	69673.30	0.00	0.00	0.00	564.80	49.38	388.00	50.35	0.0	0.00	26.70	2.15	0.00	0.00	9.83	29.30	0.00	32720.00	33360.00	0.00
Min	36	317.13	6604.00	80.00	112.60	101862.00	0.00	101862.00	67175.00	0.00	0.00	0.00	564.00	49.31	388.00	50.33	0.0	0.00	30.00	2.42	0.00	0.00	10.27	31.00	0.00	32680.00	33360.00	0.00
Max	36	317.68	6614.00	80.00	50.79	112003.00	0.00	112003.00	74046.00	0.00	0.00	0.00	566.00	49.50	388.00	50.38	0.0	0.00	20.00	1.61	0.00	0.00	9.27	32.00	0.00	32780.00	33360.00	0.00
Mean	36*	301.15	6608.00	80.00	103.96	104273.70	0.00	104273.70	68761.10	0.00	0.00	0.00	568.00	49.52	388.00	50.48	0.0	0.00	26.90	2.17	0.00	0.00	9.59	28.90	0.00	32720.00	33360.00	0.00
Min	36*	301.25	6596.00	80.00	133.68	105823.00	0.00	105823.00	69765.00	0.00	0.00	0.00	572.00	49.42	388.00	50.58	0.0	0.00	27.00	2.17	0.00	0.00	9.38	26.00	0.00	32600.00	33360.00	0.00
Max	36*	301.31	6618.00	80.00	104.16	100112.00	0.00	100112.00	66039.00	0.00	0.00	0.00	570.00	49.59	388.00	50.41	0.0	0.00	25.00	2.01	0.00	0.00	9.54	27.00	0.00	32820.00	33360.00	0.00
Case 8																												
Mean	1	300.43	7261.60	80.00	119.56	6658.40	0.00	6658.10	1513.80	0.00	0.00	0.00	293.20	23.74	734.00	76.26	0.0	0.00	26.90	4.33	0.00	0.00	7.21	25.90	0.00	17236.00	55380.00	0.00
Min	1	300.32	7248.00	80.00	9.78	6643.00	0.00	6643.00	1516.00	0.00	0.00	0.00	294.00	23.59	734.00	76.41	0.0	0.00	29.00	4.67	0.00	0.00	6.88	18.00	0.00	17100.00	55380.00	0.00
Max	1	300.60	7270.00	80.00	238.13	6600.00	0.00	6599.00	1504.00	0.00	0.00	0.00	292.00	23.82	734.00	76.18	0.0	0.00	28.00	4.51	0.00	0.00	7.23	29.00	0.00	17320.00	55380.00	0.00
Mean	12	300.58	7253.00	80.00	108.07	51930.00	0.00	51928.40	11938.30	0.00	0.00	0.00	293.40	23.61	734.00	76.24	0.0	0.00	26.50	4.27	0.00	0.00	7.49	29.10	0.00	17150.00	55380.00	0.00
Min	12	300.39	7244.00	80.00	194.52	56503.00	0.00	56501.00	12847.00	0.00	0.00	0.00	290.00	23.51	734.00	76.30	0.0	0.00	25.00	4.03	0.00	0.00	7.50	25.00	0.00	17060.00	55380.00	0.00
Max	12	300.80	7258.00	80.00	131.17	60125.00	0.00	60122.00	13812.00	0.00	0.00	0.00	296.00	23.64	734.00	76.11	0.0	0.00	25.00	4.03	0.00	0.00	7.42	32.00	0.00	17200.00	55380.00	0.00
Mean	36	312.55	7247.16	80.00	108.56	64426.60	0.00	64420.60	14820.80	0.00	0.00	0.00	293.00	23.49	734.00	76.16	0.1	0.01	27.50	4.43	0.00	0.00	6.73	24.50	0.00	17082.00	55380.00	9.60
Min	36	316.01	7228.00	80.00	2.17	70851.00	0.00	70850.00	16456.00	0.00	0.00	0.00	290.00	23.21	734.00	76.07	0.0	0.00	27.00	4.35	0.00	0.00	6.73	24.00	0.00	16900.00	55380.00	0.00
Max	36	307.82	7258.00	80.00	4.60	67089.00	0.00	67084.00	15443.00	0.00	0.00	0.00	296.00	23.67	734.00	76.20	0.0	0.00	28.00	4.51	0.00	0.00	6.46	24.00	0.00	17200.00	55380.00	0.00
Mean	36*	308.23	7251.80	80.00	107.50	71976.00	0.00	71974.20	16539.00	0.00	0.00	0.00	297.00	23.63	734.00	76.37	0.0	0.00	27.40	4.41	0.00	0.00	6.75	23.60	0.00	17138.00	55380.00	0.00
Min	36*	301.41	7238.00	80.00	156.64	71810.00	0.00	71809.00	16655.00	0.00	0.00	0.00	292.00	23.49	734.00	76.51	0.0	0.00	27.00	4.35	0.00	0.00	8.77	29.00	0.00	17000.00	55380.00	0.00
Max	36*	308.51	7256.00	80.00	217.12	71952.00	0.00	71950.00	16358.00	0.00	0.00	0.00	302.00	23.68	734.00	76.32	0.0	0.00	25.00	4.03	0.00	0.00	6.46	27.00	0.00	17180.00	55380.00	0.00
Case 9																												
Mean	1	300.49	7947.00	80.00	149.28	3693.90	0.00	3693.90	0.80	0.00	0.00	0.00	235.40	22.46	736.00	77.54	0.0	0.00	34.10	8.24	0.00	0.00	9.78	38.60	0.00	17850.00	61620.00	0.00
Min	1	300.36	7928.00	80.00	149.23	3719.00	0.00	3719.00	0.00	0.00	0.00	0.00	232.00	21.82	742.00	78.18	0.0	0.00	32.00	7.73	0.00	0.00	8.04	30.00	0.00	17300.00	61980.00	0.00
Max	1	300.63	7962.00	80.00	67.61	3677.00	0.00	3677.00	2.00	0.00	0.00	0.00	244.00	22.91	732.00	77.09	0.0	0.00	36.00	8.70	0.00	0.00	9.77	40.00	0.00	18240.00	61380.00	0.00
Mean	12	300.59	7934.00	80.00	180.56	37701.00	0.00	37701.00	299.60	0.00	0.00	0.00	233.80	22.05	739.00	77.68	0.0	0.00	36.70	8.86	0.00	0.00	10.16	36.60	0.00	17540.00	61800.00	0.00
Min	12	300.67	7926.00	80.00	226.87	37734.00	0.00	37734.00	13.00	0.00	0.00	0.00	232.00	22.00	738.00	77.54	0.0	0.00	43.00	10.39	0.00	0.00	10.15	37.00	0.00	17520.00	61740.00	0.00
Max	12	300.44	7942.00	80.00	228.90	36728.00	0.00	36728.00	12.00	0.00	0.00	0.00	240.00	22.65	732.00	77.05	0.0	0.00	34.00	8.21	0.00	0.00	10.00	38.00	0.00	18040.00	61380.00	0.00
Mean	36	313.61	7929.96	80.00	207.78	93482.70	0.00	93482.70	23.70	0.00	0.00	0.00	233.20	22.03	738.20	77.58	0.1	0.01	35.80	8.65	0.00	0.00	9.84	35.70	0.00	17538.00	61752.00	9.60
Min	36	315.20	7920.00	80.00	295.90	40566.00	0.00	40566.00	12.00	0.00	0.00	0.00	242.00	22.37	732.00	77.05	0.0	0.00	32.00	7.73	0.00	0.00	9.46	29.00	0.00	17820.00	61380.00	0.00
Max	36	313.45	7941.60	80.00	193.04	40345.00	0.00	40345.00	13.00	0.00	0.00	0.00	224.00	21.57	744.00	77.78	1.0	0.12	36.00	8.70	0.00	0.00	10.31	36.00	0.00	17220.00	62100.00	96.00
Mean	36*	302.14	7934.00	80.00	93.47	38475.00	0.00	38475.00	11.50	0.00	0.00	0.00	232.40	22.33	736.00	77.67	0.0	0.00	35.90	8.67	0.00	0.00	9.90	39.10	0.00	17720.00	61620.00	0.00
Min	36*	301.38	7922.00	80.00	231.26	38623.00	0.00	38623.00	7.00	0.00	0.00	0.00	224.00	21.46	746.00	78.54	0.0	0.00	36.00	8.70	0.00	0.00	10.62	41.00	0.00	17000.00	62220.00	0.00
Max	36*	301.58	7948.00	80.00	96.41	37978.00	0.00	37978.00	10.00	0.00	0.00	0.00	238.00	22.77	732.00	77.23	0.0	0.00	34.00	8.21	0.00	0.00	11.27	37.00	0.00	18100.00	61380.00	0.00

Table E.28: Results of the best results of GBN network cases 7, 8 and 9, for 300 seconds.

E.8 NSF best results for 300 seconds.

Symbol	Name
$\#T$	Number of Threads
t_E	Time of Execution
C	Best Cost Solution found
CA	Highest Channel Assigned
t_{sol}	Found Solution Time
$\#i$	Number of Iterations
$\#IS$	Number of Invalid Solutions
$\#G_U$	Number of Greedy Solutions Unfeasible
$\#LS_U$	Number of Local Search Solutions Unfeasible
UD	Unfeasible Degree
$\#IM$	Number of Invert Multiplex used
C_{IM}	Cost % of Invert Multiplex
$\#MX$	Number of Muxponders placed
C_{MX}	Cost % of Muxponders
$\#TX$	Number of Transponders placed
C_{TX}	Cost % of Transponders
$\#3R$	Number of $3R$ regenerators placed
C_{3R}	Cost % of $3R$ regenerators
$\#10$	Number of Multi-Hop Grooming of $10Gb/s$
$\%10$	Traffic % of Multi-Hop Grooming of $10Gb/s$
$\#40$	Number of Multi-hop Grooming of $40Gb/s$
$\%40$	Traffic % of Multi-hop Grooming of $40Gb/s$
$\bar{m}F$	Average Fragmentation at Channel Assigned
MF	Max Fragmentation at Channel Assigned
C_{IM}	Cost of Invert Multiplexers
C_{MX}	Cost of Multiplexers
C_{TX}	Cost of Transponders
C_{3R}	Cost of $3R$ regenerators

Table E.29: Header symbols and their description.

OPERATIONS	COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
	$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
Case 1																												
Mean	1	300.17	4440.40	59.00	21.08	127078.20	0.00	0.00	0.00	0.00	14.00	6.31	300.00	34.86	126.00	22.30	157.0	36.54	7.40	1.23	0.00	0.00	4.42	27.90	2800.00	15480.00	9900.00	16224.00
Min	1	300.21	4440.40	59.00	1.09	126793.00	0.00	0.00	0.00	0.00	14.00	6.31	300.00	34.86	126.00	22.30	157.0	36.54	6.00	1.00	0.00	0.00	4.05	28.00	2800.00	15480.00	9900.00	16224.00
Max	1	300.13	4440.40	59.00	42.53	127048.00	0.00	0.00	0.00	0.00	14.00	6.31	300.00	34.86	126.00	22.30	157.0	36.54	7.00	1.17	0.00	0.00	3.85	29.00	2800.00	15480.00	9900.00	16224.00
Mean	12	300.18	4440.08	59.00	35.07	1218185.60	0.00	0.00	0.00	0.00	14.00	6.31	301.60	34.90	126.00	22.30	157.4	36.49	8.40	1.40	0.00	0.00	4.64	27.20	2800.00	15496.00	9900.00	16204.80
Min	12	300.13	4438.80	59.00	53.06	1233162.00	0.00	0.00	0.00	0.00	14.00	6.31	308.00	35.04	126.00	22.30	159.0	36.32	12.00	2.00	0.00	0.00	4.80	29.00	2800.00	15560.00	9900.00	16128.00
Max	12	300.21	4440.40	59.00	4.17	1121105.00	0.00	0.00	0.00	0.00	14.00	6.31	300.00	34.86	126.00	22.30	157.0	36.54	8.00	1.33	0.00	0.00	5.10	26.00	2800.00	15480.00	9900.00	16224.00
Mean	36	312.19	4439.60	59.30	81.90	1369062.40	0.00	0.00	0.00	0.00	14.00	6.31	304.00	34.95	126.00	22.30	158.0	36.43	9.60	1.60	0.00	0.00	4.41	27.20	2800.00	15520.00	9900.00	16176.00
Min	36	313.09	4438.80	59.00	154.69	1372455.00	0.00	0.00	0.00	0.00	14.00	6.31	308.00	35.04	126.00	22.30	159.0	36.32	11.00	1.83	0.00	0.00	4.80	29.00	2800.00	15560.00	9900.00	16128.00
Max	36	318.10	4440.40	59.00	1.90	1384725.00	0.00	0.00	0.00	0.00	14.00	6.31	300.00	34.86	126.00	22.30	157.0	36.54	8.00	1.33	0.00	0.00	4.80	29.00	2800.00	15480.00	9900.00	16224.00
Mean	36*	310.23	4439.92	58.90	48.46	1329893.00	0.00	0.00	0.00	0.00	14.00	6.31	302.40	34.92	126.00	22.30	157.6	36.48	8.60	1.43	0.00	0.00	4.68	27.90	2800.00	15504.00	9900.00	16195.20
Min	36*	313.73	4438.80	58.00	282.36	1338887.00	0.00	0.00	0.00	0.00	14.00	6.31	308.00	35.05	126.00	22.30	159.0	36.33	12.00	2.00	0.00	0.00	4.15	25.00	2800.00	15560.00	9900.00	16128.00
Max	36*	307.20	4440.40	59.00	2.84	1348085.00	0.00	0.00	0.00	0.00	14.00	6.31	300.00	34.86	126.00	22.30	157.0	36.54	8.00	1.33	0.00	0.00	4.40	25.00	2800.00	15480.00	9900.00	16224.00
Case 2																												
Mean	1	300.18	4890.40	62.10	119.30	94717.80	0.00	0.00	0.00	0.00	16.00	6.54	153.20	16.58	334.00	47.24	140.8	29.64	10.60	3.53	0.00	0.00	5.20	27.70	3200.00	8108.00	23100.00	14496.00
Min	1	300.22	4882.80	62.00	292.53	94810.00	0.00	0.00	0.00	0.00	16.00	6.55	152.00	16.55	334.00	47.31	140.0	29.59	11.00	3.67	0.00	0.00	5.15	25.00	3200.00	8080.00	23100.00	14448.00
Max	1	300.22	4892.80	64.00	175.42	94602.00	0.00	0.00	0.00	0.00	16.00	6.54	154.00	16.72	334.00	47.21	140.0	29.53	13.00	4.33	0.00	0.00	4.50	28.00	3200.00	8180.00	23100.00	14448.00
Mean	12	300.17	4882.88	62.00	149.03	923456.10	0.00	0.10	0.00	0.00	16.00	6.54	152.40	16.56	334.00	47.23	139.8	29.50	12.30	4.10	0.00	0.00	5.28	29.90	3200.00	8100.00	23100.00	14428.80
Min	12	300.22	4882.80	62.00	5.48	881090.00	0.00	0.00	0.00	0.00	16.00	6.54	152.00	16.51	334.00	47.20	140.0	29.52	12.00	4.00	0.00	0.00	4.85	28.00	3200.00	8080.00	23100.00	14448.00
Max	12	300.24	4883.20	62.00	85.27	894002.00	0.00	1.00	0.00	0.00	16.00	6.55	154.00	16.74	334.00	47.26	139.0	29.36	15.00	5.00	0.00	0.00	6.00	29.00	3200.00	8180.00	23100.00	14352.00
Mean	36	310.59	4883.28	61.90	88.48	1021382.10	0.00	0.00	0.00	0.00	16.00	6.54	152.00	16.51	334.00	47.21	140.2	29.54	11.80	3.93	0.00	0.00	5.38	29.80	3200.00	8080.00	23100.00	14452.80
Min	36	313.75	4882.80	62.00	4.87	1015031.00	0.00	0.00	0.00	0.00	16.00	6.54	152.00	16.52	334.00	47.22	140.0	29.53	12.00	4.00	0.00	0.00	5.75	30.00	3200.00	8080.00	23100.00	14448.00
Max	36	306.59	4887.60	61.00	64.58	1025842.00	0.00	0.00	0.00	0.00	16.00	6.53	152.00	16.49	334.00	47.15	142.0	29.59	10.00	3.33	0.00	0.00	5.25	29.00	3200.00	8080.00	23100.00	14496.00
Mean	36*	304.58	4883.80	63.00	137.93	977443.70	0.00	0.00	0.00	0.00	16.00	6.55	152.20	16.56	334.00	47.30	140.3	29.58	11.70	3.90	0.00	0.00	5.48	31.70	3200.00	8090.00	23100.00	14448.00
Min	36*	300.92	4882.80	62.00	30.11	989799.00	0.00	0.00	0.00	0.00	16.00	6.55	152.00	16.55	334.00	47.31	140.00	29.59	12.00	4.00	0.00	0.00	5.75	35.00	3200.00	8080.00	23100.00	14448.00
Max	36*	313.79	4887.60	61.00	210.79	999177.00	0.00	0.00	0.00	0.00	16.00	6.55	152.00	16.53	334.00	47.26	142.0	29.66	10.00	3.33	0.00	0.00	5.95	38.00	3200.00	8080.00	23100.00	14496.00
Case 3																												
Mean	1	300.18	5539.24	80.00	140.65	98506.50	0.00	98506.50	0.00	0.00	24.00	8.67	101.80	10.11	356.00	47.66	171.9	33.56	7.40	3.70	0.00	0.00	5.10	32.90	4800.00	5602.00	26400.00	18590.40
Min	1	300.13	5527.20	80.00	243.80	98437.00	0.00	98437.00	0.00	0.00	24.00	8.68	100.00	10.20	356.00	47.76	171.0	33.35	8.00	4.00	0.00	0.00	5.25	29.00	4800.00	5640.00	26400.00	18432.00
Max	1	300.24	5544.00	80.00	200.15	98543.00	0.00	98543.00	0.00	0.00	24.00	8.66	104.00	9.96	356.00	47.62	174.0	33.77	6.00	3.00	0.00	0.00	5.50	37.00	4800.00	5520.00	26400.00	18720.00
Mean	12	300.18	5532.40	80.00	135.26	968573.70	0.00	968573.70	0.00	0.00	24.00	8.67	104.40	10.06	356.00	47.66	171.8	33.49	7.10	3.55	0.00	0.00	4.97	33.30	4800.00	5572.00	26400.00	18552.00
Min	12	300.13	5527.20	80.00	178.96	961251.00	0.00	961251.00	0.00	0.00	24.00	8.66	100.00	10.18	356.00	47.64	171.0	33.26	8.00	4.00	0.00	0.00	4.10	29.00	4800.00	5640.00	26400.00	18432.00
Max	12	300.25	5535.60	80.00	76.66	971192.00	0.00	971192.00	0.00	0.00	24.00	8.66	102.00	10.07	356.00	47.63	171.0	33.52	6.00	3.00	0.00	0.00	4.55	38.00	4800.00	5580.00	26400.00	18576.00
Mean	36	314.71	5529.48	80.00	119.56	1074025.70	0.00	1074025.70	0.00	0.00	24.00	8.66	105.00	10.08	356.00	47.63	171.8	33.39	7.70	3.85	0.00	0.00	4.81	31.70	4800.00	5586.00	26400.00	18508.80
Min	36	316.34	5527.20	80.00	9.42	1089072.00	0.00	1089072.00	0.00	0.00	24.00	8.67	100.00	10.19	356.00	47.70	171.0	33.30	8.00	4.00	0.00	0.00	3.75	29.00	4800.00	5640.00	26400.00	18432.00
Max	36	308.61	5534.80	80.00	79.84	1053253.00	0.00	1053253.00	0.00	0.00	24.00	8.66	106.00	10.14	356.00	47.62	172.0	33.42	9.00	4.50	0.00	0.00	4.90	26.00	4800.00	5620.00	26400.00	18528.00
Mean	36*	305.27	5530.32	80.00	111.05	1022291.90	0.00	1022291.90	0.00	0.00	24.00	8.68	103.60	10.09	356.00	47.74	171.8	33.49	6.80	3.40	0.00	0.00	5.13	32.50	4800.00	5580.00	26400.00	18523.20
Min	36*	313.52	5526.00	80.00	48.30	1062128.00	0.00	1062128.00	0.00	0.00	24.00	8.69	102.00	10.10	356.00	47.77	170.0	33.44	6.00	3.00	0.00	0.00	5.75	35.00	4800.00	5580.00	26400.00	18480.00
Max	36*	310.50	5534.80	80.00	182.32	1010072.00	0.00	1010072.00	0.00	0.00	24.00	8.67	106.00	10.15	356.00	47.70	172.0	33.48	8.00	4.00	0.00	0.00	5.25	36.00	4800.00	5620.00	26400.00	18528.00

Table E.30: Results of the best results of NSF network cases 1, 2 and 3, for 300 seconds.

OPERATIONS	COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
	$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	$\#10G$	$\%10G$	$\#40G$	$\%40G$	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
Case 4																												
Mean	1	300.21	5394.20	59.40	150.94	35861.70	0.00	0.00	0.00	0.00	20.00	7.42	405.40	37.90	162.00	23.36	164.3	31.32	18.70	2.40	0.00	0.00	3.79	29.70	4000.00	20446.00	12600.00	16896.00
Min	1	300.16	5374.80	60.00	190.54	35300.00	0.00	0.00	0.00	0.00	20.00	7.44	406.00	37.77	162.00	23.44	165.0	31.35	19.00	2.44	0.00	0.00	3.65	27.00	4000.00	20300.00	12600.00	16848.00
Max	1	300.16	5400.40	60.00	163.85	35862.00	0.00	0.00	0.00	0.00	20.00	7.41	406.00	37.89	162.00	23.33	166.0	31.38	20.00	2.56	0.00	0.00	4.25	35.00	4000.00	20460.00	12600.00	16944.00
Mean	12	300.25	5382.92	59.60	196.43	343478.30	0.00	0.00	0.00	0.00	20.00	7.41	402.60	37.85	162.00	23.34	161.9	31.11	18.70	2.40	0.00	0.00	4.11	32.30	4000.00	20434.00	12600.00	16795.20
Min	12	300.25	5373.60	59.00	168.89	338127.00	0.00	0.00	0.00	0.00	20.00	7.41	400.00	37.91	162.00	23.33	160.0	30.84	24.00	3.08	0.00	0.00	4.10	35.00	4000.00	20480.00	12600.00	16656.00
Max	12	300.28	5387.60	61.00	74.97	342816.00	0.00	0.00	0.00	0.00	20.00	7.41	406.00	38.22	162.00	23.35	160.0	30.87	25.00	3.21	0.00	0.00	4.45	37.00	4000.00	20620.00	12600.00	16656.00
Mean	36	313.23	5387.52	59.30	134.45	390407.20	0.00	0.00	0.00	0.00	20.00	7.41	404.00	37.79	162.00	23.33	163.7	31.24	20.30	2.60	0.00	0.00	4.21	31.50	4000.00	20408.00	12600.00	16867.20
Min	36	311.45	5377.20	59.00	3.67	391295.00	0.00	0.00	0.00	0.00	20.00	7.41	402.00	37.81	162.00	23.33	161.0	31.02	24.00	3.08	0.00	0.00	3.75	36.00	4000.00	20420.00	12600.00	16752.00
Max	36	314.22	5394.80	59.00	62.78	395581.00	0.00	0.00	0.00	0.00	20.00	7.41	410.00	38.00	162.00	23.36	165.0	31.23	17.00	2.18	0.00	0.00	4.55	36.00	4000.00	20500.00	12600.00	16848.00
Mean	36*	307.82	5384.64	59.50	132.82	378494.00	0.00	0.00	0.00	0.00	20.00	7.43	404.00	37.90	162.00	23.40	163.1	31.27	18.80	2.41	0.00	0.00	4.13	28.20	4000.00	20408.00	12600.00	16838.40
Min	36*	300.85	5376.40	60.00	219.48	372782.00	0.00	0.00	0.00	0.00	20.00	7.44	406.00	38.06	162.00	23.44	162.0	31.07	16.00	2.05	0.00	0.00	3.70	36.00	4000.00	20460.00	12600.00	16704.00
Max	36*	301.14	5391.60	60.00	178.51	374582.00	0.00	0.00	0.00	0.00	20.00	7.42	402.00	37.87	162.00	23.37	164.0	31.34	18.00	2.31	0.00	0.00	4.15	22.00	4000.00	20420.00	12600.00	16896.00
Case 5																												
Mean	1	300.23	6781.44	79.90	154.58	42307.50	0.00	18861.00	748.00	0.00	16.60	4.90	193.40	15.53	439.40	45.43	217.3	34.14	11.60	2.97	0.00	0.00	7.94	45.30	3320.00	10534.00	30810.00	23150.40
Min	1	300.19	6768.40	80.00	64.83	42061.00	0.00	18734.00	740.00	0.00	18.00	5.32	198.00	15.57	438.00	45.21	218.0	33.90	11.00	2.82	0.00	0.00	7.95	43.00	3600.00	10540.00	30600.00	22944.00
Max	1	300.18	6790.00	80.00	126.19	42297.00	0.00	18879.00	714.00	0.00	16.00	4.71	204.00	15.49	440.00	45.51	220.0	34.29	12.00	3.08	0.00	0.00	8.20	45.00	3200.00	10520.00	30900.00	23280.00
Mean	12	300.32	6764.24	79.80	154.34	397053.10	0.00	176889.30	6963.90	0.00	17.20	5.07	194.00	15.55	438.80	45.28	216.1	33.81	12.60	3.23	0.00	0.00	7.79	43.90	3440.00	10548.00	30720.00	22934.40
Min	12	300.78	6748.80	80.00	239.26	384789.00	0.00	171506.00	6785.00	0.00	18.00	5.30	196.00	15.38	438.00	45.08	217.0	33.66	11.00	2.82	0.00	0.00	8.20	44.00	3600.00	10440.00	30600.00	22848.00
Max	12	300.44	6780.40	80.00	51.42	416615.00	0.00	185553.00	7376.00	0.00	18.00	5.31	194.00	15.72	438.00	45.12	218.0	33.83	15.00	3.85	0.00	0.00	7.25	41.00	3600.00	10660.00	30600.00	22944.00
Mean	36	312.69	6764.72	79.90	175.97	447972.30	0.00	199553.20	7875.20	0.00	16.80	4.94	193.60	15.42	439.20	45.23	216.3	33.82	11.20	2.87	0.00	0.00	7.99	44.50	3360.00	10496.00	30780.00	23011.20
Min	36	312.87	6755.60	80.00	233.45	444894.00	0.00	198091.00	7702.00	0.00	18.00	5.30	190.00	15.41	438.00	45.08	216.0	33.73	10.00	2.56	0.00	0.00	8.00	42.00	3600.00	10460.00	30600.00	22896.00
Max	36	311.25	6777.20	80.00	287.46	443237.00	0.00	197694.00	7836.00	0.00	16.00	4.71	196.00	15.35	440.00	45.43	218.0	34.16	10.00	2.56	0.00	0.00	7.40	44.00	3200.00	10440.00	30900.00	23232.00
Mean	36*	304.37	6765.48	80.00	185.14	409652.00	0.00	182528.70	7243.50	0.00	17.00	5.03	192.40	15.50	439.00	45.45	216.1	34.03	11.10	2.85	0.00	0.00	7.97	43.90	3400.00	10484.00	30750.00	23020.80
Min	36*	307.16	6754.40	80.00	176.59	396815.00	0.00	177176.00	7132.00	0.00	18.00	5.33	192.00	15.40	438.00	45.30	218.0	33.97	10.00	2.56	0.00	0.00	8.35	48.00	3600.00	10400.00	30600.00	22944.00
Max	36*	300.75	6777.20	80.00	154.77	415161.00	0.00	184926.00	7432.00	0.00	16.00	4.72	196.00	15.40	440.00	45.59	218.0	34.28	9.00	2.31	0.00	0.00	7.65	39.00	3200.00	10440.00	30900.00	23232.00
Case 6																												
Mean	1	300.25	7351.80	78.60	131.58	39516.40	0.00	8108.50	0.00	0.00	27.60	7.51	137.80	9.92	466.40	47.42	239.7	35.16	15.40	5.92	0.00	0.00	5.91	29.70	5520.00	7290.00	34860.00	25848.00
Min	1	300.18	7339.60	79.00	90.59	39482.00	0.00	8073.00	0.00	0.00	28.00	7.63	138.00	9.84	466.00	47.41	240.0	35.12	14.00	5.38	0.00	0.00	5.30	28.00	5600.00	7220.00	34800.00	25776.00
Max	1	300.18	7360.40	78.00	274.56	39615.00	0.00	8099.00	0.00	0.00	28.00	7.61	138.00	10.03	466.00	47.28	239.0	35.09	18.00	6.92	0.00	0.00	5.00	22.00	5600.00	7380.00	34800.00	25824.00
Mean	12	300.25	7340.00	78.80	136.33	384948.70	0.00	79033.80	0.00	0.00	28.00	7.62	137.60	9.86	466.00	47.33	238.7	35.02	14.50	5.58	0.00	0.00	6.35	33.10	5600.00	7248.00	34800.00	25752.00
Min	12	300.33	7328.80	78.00	285.15	388491.00	0.00	79793.00	0.00	0.00	28.00	7.62	140.00	9.75	466.00	47.38	238.0	35.03	15.00	5.77	0.00	0.00	6.25	38.00	5600.00	7160.00	34800.00	25728.00
Max	12	300.21	7346.40	78.00	57.42	384752.00	0.00	79287.00	0.00	0.00	28.00	7.61	132.00	9.84	466.00	47.29	239.0	35.09	16.00	6.15	0.00	0.00	6.30	33.00	5600.00	7240.00	34800.00	25824.00
Mean	36	310.71	7341.24	79.10	125.58	420025.40	0.00	86296.80	0.00	0.00	28.00	7.61	137.40	9.88	466.00	47.28	239.2	34.97	14.80	5.69	0.00	0.00	6.11	31.80	5600.00	7270.00	34800.00	25742.40
Min	36	309.78	7335.60	79.00	247.32	426976.00	0.00	87562.00	0.00	0.00	28.00	7.62	134.00	9.76	466.00	47.32	240.0	35.05	13.00	5.00	0.00	0.00	5.80	32.00	5600.00	7180.00	34800.00	25776.00
Max	36	315.56	7346.40	79.00	25.33	403912.00	0.00	82447.00	0.00	0.00	28.00	7.61	132.00	9.84	466.00	47.28	239.0	35.09	15.00	5.77	0.00	0.00	4.75	23.00	5600.00	7240.00	34800.00	25824.00
Mean	36*	307.89	7339.40	79.00	95.58	412056.50	0.00	84605.70	0.00	0.00	28.00	7.63	137.00	9.90	466.00	47.42	238.6	35.05	16.10	6.19	0.00	0.00	6.19	31.40	5600.00	7266.00	34800.00	25728.00
Min	36*	300.85	7334.00	80.00	129.12	399481.00	0.00	81946.00	0.00	0.00	28.00	7.64	142.00	9.90	466.00	47.45	239.0	35.02	21.00	8.08	0.00	0.00	7.25	30.00	5600.00	7260.00	34800.00	25680.00
Max	36*	310.27	7344.80	79.00	53.60	410129.00	0.00	84483.00	0.00	0.00	28.00	7.62	140.00	9.97	466.00	47.38	238.0	35.03	16.00	6.15	0.00	0.00	5.65	33.00	5600.00	7320.00	34800.00	25728.00

Table E.31: Results of the best results of NSF network cases 4, 5 and 6, for 300 seconds.

OPERATIONS	COMPUTATIONAL RESULTS										INVERSE MULT.		FIXED GRID						MULTI-HOP GROOMING				GAP		COST			
	$\#T$	t_E	C	CA	t_{sol}	$\#i$	$\#IS$	$\#G_U$	$\#LS_U$	UD	$\#IM$	C_{IM}	$\#MX$	C_{MX}	$\#TX$	C_{TX}	$\#3R$	C_{3R}	#10G	%10G	#40G	%40G	$\bar{m}F$	MF	C_{IM}	C_{MX}	C_{TX}	C_{3R}
Case 7																												
Mean	1	300.30	7823.32	80.00	113.97	11596.80	0.00	11596.80	2073.00	0.00	16.40	4.19	501.00	34.90	221.60	22.93	253.5	37.97	34.90	3.44	0.00	0.00	4.35	35.00	3280.00	27306.00	17940.00	29707.20
Min	1	300.36	7785.20	80.00	61.79	11663.00	0.00	11663.00	2187.00	0.00	14.00	3.60	496.00	34.73	224.00	23.51	251.0	38.16	31.00	3.06	0.00	0.00	4.75	33.00	2800.00	27040.00	18300.00	29712.00
Max	1	300.22	7857.60	80.00	16.52	11628.00	0.00	11628.00	2087.00	0.00	14.00	3.56	506.00	34.85	224.00	23.29	258.0	38.30	35.00	3.45	0.00	0.00	4.00	33.00	2800.00	27380.00	18300.00	30096.00
Mean	12	300.39	7797.32	80.00	120.43	316430.00	0.00	316430.00	20786.40	0.00	15.00	3.83	499.00	34.64	222.80	23.14	253.5	37.94	31.00	3.06	0.00	0.00	4.52	35.40	3000.00	27126.00	18120.00	29707.20
Min	12	300.27	7770.00	80.00	226.20	115977.00	0.00	115977.00	21162.00	0.00	16.00	4.10	506.00	34.88	222.00	23.07	254.0	37.52	36.00	3.55	0.00	0.00	4.15	41.00	3200.00	27220.00	18000.00	29280.00
Max	12	300.39	7822.40	80.00	112.55	113731.00	0.00	113731.00	20887.00	0.00	14.00	3.57	498.00	34.45	224.00	23.36	257.0	38.49	28.00	2.76	0.00	0.00	3.80	26.00	2800.00	26980.00	18300.00	30144.00
Mean	36	314.52	7797.96	80.00	162.68	128451.20	0.00	128451.20	23227.50	0.00	16.00	4.06	498.80	34.48	221.80	22.81	253.1	37.60	30.90	3.05	0.00	0.00	4.66	36.00	3200.00	27164.00	17970.00	29625.60
Min	36	314.96	7774.40	80.00	286.65	128245.00	0.00	128245.00	23052.00	0.00	14.00	3.56	506.00	34.61	224.00	23.27	254.0	37.41	31.00	3.06	0.00	0.00	4.10	38.00	2800.00	27220.00	18300.00	29424.00
Max	36	325.32	7810.80	80.00	99.29	134734.00	0.00	134734.00	24156.00	0.00	16.00	4.04	502.00	34.52	222.00	22.73	251.0	37.34	38.00	3.75	0.00	0.00	5.75	48.00	3200.00	27340.00	18000.00	29568.00
Mean	36*	307.67	7801.96	79.90	152.18	126578.40	0.70	126578.40	22938.20	0.00	16.00	4.10	497.40	34.79	221.80	23.03	251.0	38.06	31.20	3.08	0.00	0.00	4.30	34.70	3200.00	27142.00	17970.00	29697.60
Min	36*	314.20	7791.20	80.00	35.57	127640.00	1.00	127640.00	22973.00	0.00	14.00	3.59	494.00	34.78	224.00	23.49	248.0	38.14	30.00	2.96	0.00	0.00	3.10	25.00	2800.00	27100.00	18300.00	29712.00
Max	36*	301.33	7820.40	80.00	85.99	123857.00	2.00	123857.00	22390.00	0.00	20.00	5.11	498.00	34.70	218.00	22.25	258.0	37.93	27.00	2.66	0.00	0.00	4.55	28.00	4000.00	27140.00	17400.00	29664.00
Case 8																												
Mean	1	300.33	8377.44	80.00	164.58	11601.60	0.00	11601.60	521.60	0.00	19.60	4.68	230.40	16.52	574.40	48.27	240.9	30.53	22.60	4.46	0.00	0.00	3.52	23.30	3920.00	13840.00	40440.00	25574.40
Min	1	300.39	8349.20	80.00	169.88	11617.00	0.00	11617.00	524.00	0.00	18.00	4.31	230.00	16.27	576.00	48.72	240.0	30.70	20.00	3.94	0.00	0.00	3.80	26.00	3600.00	13580.00	40680.00	25632.00
Max	1	300.39	8392.40	80.00	190.16	11573.00	0.00	11573.00	499.00	0.00	20.00	4.77	228.00	16.63	574.00	48.12	244.0	30.48	22.00	4.34	0.00	0.00	3.40	23.00	4000.00	13960.00	40380.00	25584.00
Mean	12	300.37	8359.68	79.90	153.01	114518.70	0.00	114518.70	5113.10	0.00	20.00	4.77	230.80	16.50	574.00	48.14	240.6	30.25	19.50	3.85	0.00	0.00	3.82	22.20	4000.00	13844.00	40380.00	25372.80
Min	12	300.27	8338.00	80.00	145.53	117233.00	0.00	117233.00	5176.00	0.00	20.00	4.77	236.00	16.73	574.00	48.11	236.0	29.74	30.00	5.92	0.00	0.00	4.80	26.00	4000.00	14040.00	40380.00	24960.00
Max	12	300.27	8372.40	80.00	94.83	117733.00	0.00	117733.00	5347.00	0.00	20.00	4.76	224.00	16.39	574.00	48.10	241.0	30.47	15.00	2.96	0.00	0.00	4.45	24.00	4000.00	13760.00	40380.00	25584.00
Mean	36	313.12	8363.80	80.00	95.80	126288.20	0.00	126288.20	5617.00	0.00	19.60	4.67	228.60	16.52	574.40	48.19	239.1	30.29	21.00	4.14	0.00	0.00	4.16	23.50	3920.00	13862.00	40440.00	25416.00
Min	36	317.46	8352.40	80.00	15.49	129062.00	0.00	129062.00	5897.00	0.00	20.00	4.76	228.00	16.42	574.00	48.03	240.0	30.15	21.00	4.14	0.00	0.00	5.00	32.00	4000.00	13800.00	40380.00	25344.00
Max	36	312.78	8373.60	80.00	56.35	124432.00	0.00	124432.00	5516.00	0.00	18.00	4.30	224.00	16.61	576.00	48.55	236.0	30.48	25.00	4.93	0.00	0.00	4.30	21.00	3600.00	13920.00	40680.00	25536.00
Mean	36*	307.23	8358.16	79.90	155.02	123148.70	0.00	123148.70	5549.30	0.00	19.60	4.69	230.80	16.56	574.40	48.38	239.3	30.36	21.20	4.18	0.00	0.00	3.74	22.60	3920.00	13844.00	40440.00	25377.60
Min	36*	301.20	8338.00	80.00	150.88	122793.00	0.00	122793.00	5604.00	0.00	20.00	4.80	236.00	16.84	574.00	48.43	236.0	29.94	30.00	5.92	0.00	0.00	4.80	26.00	4000.00	14040.00	40380.00	24960.00
Max	36*	308.97	8370.00	80.00	247.01	120140.00	0.00	120140.00	5410.00	0.00	20.00	4.78	236.00	16.58	574.00	48.24	241.0	30.39	19.00	3.75	0.00	0.00	3.60	25.00	4000.00	13880.00	40380.00	25440.00
Case 9																												
Mean	1	300.37	10138.88	80.00	189.62	8310.40	0.00	8310.40	3770.10	0.00	21.80	4.30	206.00	15.85	548.00	42.03	282.6	37.03	28.00	8.28	0.00	0.00	1.91	12.60	4360.00	16070.00	42618.00	37540.80
Min	1	300.47	10078.40	80.00	160.09	8248.00	0.00	8248.00	3693.00	0.00	20.00	3.97	208.00	15.62	554.00	42.80	277.0	36.82	29.00	8.58	0.00	0.00	1.85	14.00	4000.00	15740.00	43140.00	37104.00
Max	1	300.24	10221.20	80.00	195.53	8318.00	0.00	8318.00	3786.00	0.00	20.00	3.91	210.00	15.93	548.00	41.85	287.0	37.52	31.00	9.17	0.00	0.00	1.15	9.00	4000.00	16280.00	42780.00	38352.00
Mean	12	300.34	10064.20	80.00	316.14	74708.10	0.00	74708.10	33618.20	0.00	24.80	4.93	205.60	15.91	547.00	42.04	286.1	37.75	28.20	8.34	0.10	0.04	2.79	18.50	4960.00	16006.00	42306.00	37992.00
Min	12	300.35	9964.40	80.00	272.45	75150.00	0.00	75150.00	33817.00	0.00	26.00	5.22	214.00	16.92	540.00	41.73	289.0	37.96	28.00	8.28	0.00	0.00	4.10	28.00	5200.00	16860.00	41580.00	37824.00
Max	12	300.44	10122.80	80.00	117.92	74538.00	0.00	74538.00	33542.00	0.00	22.00	4.35	210.00	15.87	550.00	42.20	277.0	36.80	30.00	8.88	0.00	0.00	2.60	11.00	4400.00	16060.00	42720.00	37248.00
Mean	36	300.37	10055.28	80.00	141.84	92372.39	0.00	92372.10	41567.10	0.00	21.80	4.34	201.00	15.58	552.40	42.68	282.1	37.14	25.50	7.54	0.10	0.04	1.92	12.00	4360.00	15670.00	42918.00	37348.80
Min	36	300.24	9992.00	80.00	194.06	90513.60	0.00	90513.00	40731.00	0.00	22.00	4.40	202.00	15.29	554.00	42.99	278.0	36.51	25.00	7.40	0.00	0.00	2.00	18.00	4400.00	15280.00	42960.00	36480.00
Max	36	300.22	10114.00	80.00	10.16	93304.10	0.00	93304.00	41986.00	0.00	16.00	3.16	202.00	14.83	566.00	43.72	284.0	37.49	25.00	7.40	0.00	0.00	2.15	9.00	3200.00	15000.00	44220.00	37920.00
Mean	36*	300.36	9992.40	80.00	217.39	88786.18	0.00	88785.90	39953.20	0.00	22.60	4.53	197.80	15.34	555.80	43.01	282.6	37.27	28.10	8.31	0.00	0.00	2.26	14.80	4520.00	15330.00	42960.00	37224.00
Min	36*	300.44	9470.40	80.00	285.73	88213.20	0.00	88213.10	39695.00	0.00	26.00	5.49	188.00	15.14	568.00	45.87	286.0	39.94	29.00	8.58	0.00	0.00	4.75	40.00	5200.00	14340.00	43440.00	37824.00
Max	36*	300.42	10104.00	80.00	241.80	91036.80	0.00	91036.00	40966.00	0.00	26.00	5.15	208.00	15.68	552.00	42.04	282.0	36.34	34.00	10.06	0.00	0.00	1.30	10.00	5200.00	15840.00	42480.00	36720.00

Table E.32: Results of the best results of NSF network cases 7, 8 and 9, for 300 seconds.